Electric vehicles in Nova Scotia: An examination of availability, affordability, and acceptability issues

Larry Hughes, PhD
Dalhousie University
Halifax, Nova Scotia, Canada
11 January 2016
Revised: 2 November 2016

Abstract

In December 2015, the Canadian government made a commitment to achieving the goals specified in the Paris Agreement at COP-21. The most significant of these commitments being an agreement to reduce Canada’s annual greenhouse gas emissions to a level that will hold the global average temperature to well below 2°C and to pursue efforts to limit the temperature increase to 1.5°C. Past greenhouse gas emissions reduction efforts by all levels of government in Canada have focused primarily on power generation (to reduce emissions) and the built environment (to reduce energy demand). Canada’s commitment to the Paris Agreement means that these efforts must be redoubled and similar efforts will need to be applied to the transportation sector, given the emissions associated with this sector.

Road transportation emissions are of particular importance in a province such as Nova Scotia where they are responsible for over 19% of total provincial emissions. A barrier to reducing emissions from conventional road vehicles has been the availability of both alternative fuels and the vehicles to use these fuels. However, over the past decade, considerable progress has been made, especially with electric vehicles, which, if powered by renewable sources of electricity, can result in a reduction in transportation-related emissions.

This report examines some of the risks associated with the adoption of electric vehicles in the province of Nova Scotia through the lens of three energy security indicators: acceptability, availability, and affordability. It shows that as Nova Scotia Power reduces its greenhouse gas emissions, the environmental acceptability of electric vehicles will increase, albeit not nearly to the degree found in jurisdictions with very low emissions intensity such as Quebec and Ontario. While the availability of electricity is not an issue, the need for increased charging may be a problem during cold-weather driving and, should electric vehicles become popular, Nova Scotia Power will need to address the issue of uncoordinated electricity charging by upgrading its grid and implementing a smart grid.

The report also considers some of the affordability issues associated with electric vehicles in Nova Scotia. While the per-kilometre cost of driving an electric vehicle is less than that of a conventional vehicle (in part because of the various road and fuel taxes that electric vehicle owners do not pay), both the base-cost and annualized-cost of electric vehicles are greater than those associated with many conventional vehicles sold in the province.

Other topics discussed include public perceptions of electric vehicles, the direct and indirect subsidization of electric vehicles, electric-buses.
**Glossary**

- **BEV**: Battery Electric Vehicle – a vehicle using electricity for all its motive power
- **CV**: Conventional Vehicle – a vehicle using a liquid fuel for all its motive power
- **EV**: Electric Vehicle – a BEV, HEV, or PHEV
- **EVSE**: Electric Vehicle Supply Equipment – a device for charging EVs
- **g**: gram
- **Gt**: Gigatonne (one billion or \(1 \times 10^9\) tonnes)
- **GtCO\(_2\)e**: Gigatonnes carbon-dioxide equivalent
- **h**: Hour
- **HEMS**: Home Energy Management System
- **HEV**: Hybrid Electric Vehicle – a vehicle converting a liquid fuel to electricity for its motive power
- **ICE**: Internal Combustion Engine
- **ICT**: Information and Communications Technology
- **kg**: kilogram (1,000 g)
- **km**: kilometre
- **kt**: kiloton (1,000 or \(1 \times 10^3\) tonnes)
- **kWh**: kilowatt-hour
- **L**: Litre
- **MM\$**: Million dollars
- **Mt**: Megatonne (one million or \(1 \times 10^6\) tonnes)
- **NRCan**: Natural Resources Canada
- **NSP**: Nova Scotia Power
- **PHEV**: Plug-in Hybrid Electric Vehicle – a hybrid vehicle using both mains electricity and a liquid fuel for its motive power
- **PM2.5**: Particulate Matter 2.5 micron
- **PM10**: Particulate Matter 10 micron
- **t**: tonne (1,000 kg)

**Acknowledgements**

The author would like to thank Sanjeev Pushkarna of Nova Scotia Power for proposing the idea of an investigation into electric vehicles in Nova Scotia. He would also like to thank his colleagues Raphael Sauter, Jaroslav Hajek, Moniek de Jong, Ryan Murphy, and Sandy Cook for their comments on earlier versions of this report. The anonymous reviewers selected by Nova Scotia Power also made useful suggestions.
Electric vehicles in Nova Scotia: 
An examination of availability, affordability, and acceptability issues
Larry Hughes, PhD

1 Introduction

One of Prime Minister Trudeau’s many commitments at the COP21 climate conference held in Paris in December 2015 was to meet Canada’s Intended Nationally Determined Contributions (INDC) emissions reduction target (UNFCCC, 2015; Mas & Cullen, 2016). The target, originally specified by the Harper government in May 2015, states that Canada plans to reduce its greenhouse gas emissions by 30% from 2005 levels by 2030 (INDC, 2015).

Although it is broadly accepted that Canada will not meet its 2030 INDC target (Climate Policy Observer, n.d.), Nova Scotia’s emissions had declined from 23.5 Mt to 16.6 Mt, or 29.4% below those in 2005, just shy of the INDC target (Hughes, 2016), as shown in Table 1. With the exception of emissions from resource extraction, emissions from all sectors declined in the province.

Table 1: Changes in emissions between 2005 and 2014 for Canada and Nova Scotia (Mt) (Canada, 2015a)

<table>
<thead>
<tr>
<th>Emissions source</th>
<th>Canada</th>
<th>Nova Scotia</th>
<th>Change</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>747</td>
<td>732</td>
<td>-2.0%</td>
<td>23.5</td>
</tr>
<tr>
<td>Electricity generation</td>
<td>124.0</td>
<td>85.5</td>
<td>-31.0%</td>
<td>10.8</td>
</tr>
<tr>
<td>Built environment</td>
<td>77.5</td>
<td>76.9</td>
<td>-0.8%</td>
<td>2.67</td>
</tr>
<tr>
<td>Road transportation</td>
<td>195.0</td>
<td>203.0</td>
<td>4.1%</td>
<td>6.01</td>
</tr>
</tbody>
</table>

About half of this decline can be attributed to legislation subjecting Nova Scotia Power an annual, declining emissions cap and an increasing renewable energy target and a significant decline in electricity demand because of the closure of two paper mills and an ongoing slowdown in the manufacturing sector. The other half of the seven megatonne reduction during this period was the result of a 23% decline in energy demand for most types of transportation, the closure of the province’s oil refinery, and changes to the ways buildings are heated (for example, from fuel oil to natural gas or electricity).

Despite having already met the national INDC target, and with the likelihood of emissions falling to 46% below 2005 levels by 2030 (Hughes, 2016), federal legislation will require the province to institute some form of carbon-pricing by 2018 (either an emissions-trading program for major emitters or a carbon-levy for the end-users of carbon-based energy sources such as gasoline, electricity, and home-heating fuel) (Canada, 2016; McCarthy, 2016). The carbon-price starts at

---

1 Emissions from resource extraction (not shown in Table 1) grew by 120%, from 0.33 Mt to 0.72 Mt (Environment Canada, 2016).
$10/tonne in 2018 and increases by $10/tonne per year, reaching $50/tonne in 2022 (Canada, 2016).

To date, the Nova Scotia government has focused its emissions reduction efforts on electricity generation and, to a lesser extent, the built-environment. The federal carbon-pricing will affect these sectors and the road transportation sector.

The ability to transport both people and goods is essential to the economic wellbeing of any jurisdiction (World Bank, 2015). Many of the significant economic and social changes that have taken place over the last 120 years are due, at least in part, to the evolution of local, national, and global transportation systems (Wolf, 1996). An essential component of these improvements has been the availability of supplies of crude oil that can be refined into transportation fuels such as gasoline/petrol, diesel, aviation fuel, and marine bunkers (IEA, 2014).

However, the past quarter century has seen growing concerns over the social and environmental impacts of crude oil extraction, refining, and transportation, the volatility of crude oil prices, and emissions (including various greenhouse gases, nitrogen oxides, and particulate matter, notably PM10 and PM2.5) associated with the combustion of refined petroleum products. In response, a number of jurisdictions have called for the introduction of cleaner vehicles and have given incentives to both manufacturers and consumers. These alternative-fuel vehicles rely on a variety of fuels (including ethanol, gasoline, natural gas, propane, and electricity) and conversion technologies (typically internal combustion engines or electric motors, or both).

Of the different types of alternative-fuel vehicles on the market, one that is of interest to many electricity suppliers and promoters of these vehicles is the battery-electric vehicle or BEV. Given the right electricity-supplier fuel-mix and climate conditions, a BEV can have both fewer emissions and lower fuel-costs than a comparable conventional vehicle with an internal combustion engine (ICE) operating on a liquid fuel such as a gasoline or diesel.

This report examines some of the issues facing a jurisdiction if its existing conventional and hybrid-electric light-duty vehicles are replaced by battery-electric light-duty vehicles. The risks are discussed in terms of three energy-security indicators (Hughes, 2012; Hughes & Ranjan, 2013):

**Availability:** The availability of both the vehicle and the energy needed by the vehicle to allow the driver and any passengers to reach their intended destination in a timely manner.

**Affordability:** The cost of the energy used by the vehicle, the lifetime cost of owning and operating the vehicle, as well as a variety of societal costs.

**Acceptability:** The greenhouse-gas emissions associated with the vehicle.

The indicators are applied to Nova Scotia, where the electricity supplier, Nova Scotia Power, is in the process of reducing its greenhouse gas emissions from over 900 kg of CO₂e/MWh in 2005 to a projected 400 kg of CO₂e/MWh by 2035. The report shows that while battery-electric vehicles will be more environmentally acceptable in the province, there may be availability and affordability issues that limit their adoption. Despite these possible shortcomings, the report briefly examines other battery-electric passenger-vehicle options that offer the province a way to take advantage of electric transportation.
2 Background

2.1 Vehicle categories and terminology

This report considers four categories of light-duty vehicle, classified by the type of fuel they use (gasoline or electricity, or both) and how the fuel is transformed into rotary motion (gasoline engine or electric motor, or both).

Vehicles that rely on a liquid fuel (typically gasoline or petrol) fall into one of two categories:

**CV**: Conventional vehicles that use an engine to convert the liquid fuel into kinetic energy for its motive power.

**HEV**: A hybrid-electric vehicle derives its motive power from an electric motor with electricity supplied by an on-board gasoline or diesel generator. Energy is stored in both batteries and a fuel tank.

Plug-in electric vehicles (or PEVs) are, as the name suggests, vehicles that derive some or all of their motive power from an external source of electricity. Broadly speaking, these fall into one of (PlugInCars, 2015):

**BEV**: A battery electric vehicle is one which derives all of its motive power from mains electricity, with the energy stored in batteries.

**PHEV**: A plug-in hybrid-electric vehicle derives a portion of its motive power from mains electricity, the remainder comes from an on-board gasoline or diesel generator. Energy is stored in both batteries and a fuel tank.

2.2 Five-cycle testing

The energy intensity (energy consumed per kilometre) and range data for the four different vehicle categories examined in this report are taken from NRCan’s 2015 Fuel Consumption Guide (NRCan, 2015a). The data in the 2015 Fuel Consumption Guide is obtained from a five-cycle testing method that more closely represents typical driving conditions than the earlier three-cycle method (NRCan, 2015b). These tests are applied to all vehicles listed in its Fuel Consumption Guide and are shown in Table 2.
## Table 2: NRCan’s five cycle tests and associated test parameters (from (NRCan, 2015b))

<table>
<thead>
<tr>
<th>Test parameters</th>
<th>Cycle test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>City</td>
</tr>
<tr>
<td>Test Cell Temperature</td>
<td>20°-30°C</td>
</tr>
<tr>
<td>Total time (minutes seconds)</td>
<td>31' 14&quot;</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>17.8 km</td>
</tr>
<tr>
<td>Top speed (km/h)</td>
<td>90 km/h</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>34 km/h</td>
</tr>
<tr>
<td>Number of stops</td>
<td>23</td>
</tr>
<tr>
<td>Idling time (% of total time)</td>
<td>18%</td>
</tr>
<tr>
<td>Engine start</td>
<td>Cold</td>
</tr>
<tr>
<td></td>
<td>Highway</td>
</tr>
<tr>
<td>Test Cell Temperature</td>
<td>20°-30°C</td>
</tr>
<tr>
<td>Total time (minutes seconds)</td>
<td>12' 45&quot;</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>16.5 km</td>
</tr>
<tr>
<td>Top speed (km/h)</td>
<td>97 km/h</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>78 km/h</td>
</tr>
<tr>
<td>Number of stops</td>
<td>0</td>
</tr>
<tr>
<td>Idling time (% of total time)</td>
<td>0%</td>
</tr>
<tr>
<td>Engine start</td>
<td>Warm</td>
</tr>
<tr>
<td></td>
<td>Cold</td>
</tr>
<tr>
<td>Test Cell Temperature</td>
<td>-7°C</td>
</tr>
<tr>
<td>Total time (minutes seconds)</td>
<td>31' 14&quot;</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>17.8 km</td>
</tr>
<tr>
<td>Top speed (km/h)</td>
<td>90 km/h</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>34 km/h</td>
</tr>
<tr>
<td>Number of stops</td>
<td>23</td>
</tr>
<tr>
<td>Idling time (% of total time)</td>
<td>18%</td>
</tr>
<tr>
<td>Engine start</td>
<td>Cold</td>
</tr>
<tr>
<td></td>
<td>Warm</td>
</tr>
<tr>
<td>Test Cell Temperature</td>
<td>35°C</td>
</tr>
<tr>
<td>Total time (minutes seconds)</td>
<td>9' 56&quot;</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>5.8 km</td>
</tr>
<tr>
<td>Top speed (km/h)</td>
<td>88 km/h</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>35 km/h</td>
</tr>
<tr>
<td>Number of stops</td>
<td>5</td>
</tr>
<tr>
<td>Idling time (% of total time)</td>
<td>19%</td>
</tr>
<tr>
<td>Engine start</td>
<td>Warm</td>
</tr>
<tr>
<td></td>
<td>Warm</td>
</tr>
<tr>
<td>Test Cell Temperature</td>
<td>20°-30°C</td>
</tr>
<tr>
<td>Total time (minutes seconds)</td>
<td>9' 56&quot;</td>
</tr>
<tr>
<td>Distance (km)</td>
<td>12.9 km</td>
</tr>
<tr>
<td>Top speed (km/h)</td>
<td>129 km/h</td>
</tr>
<tr>
<td>Average speed (km/h)</td>
<td>78 km/h</td>
</tr>
<tr>
<td>Maximum acceleration (km/h per second)</td>
<td>13.6 km/h per second</td>
</tr>
</tbody>
</table>

2.3 Vehicles considered

Unless otherwise indicated, the report considers only those light-duty passenger vehicles with the best fuel consumption rating in their category (i.e., conventional, hybrid-electric, plug-in hybrid-electric, or electric). There are two reasons for this: first, they represent a baseline for their category’s acceptability and affordability; any other vehicle considered in that category will be less acceptable and less affordable. Second, by limiting the number of vehicles considered, it improves the readability of graphs.

The vehicle ranges, when listed, assume a fully charged battery or a full tank of fuel, while the recharge time is the time required to fully recharge a battery at 240 volts. “Combined driving” refers to an average of 55% city driving and 45% highway driving. NRCan’s vehicle classes are listed in Table 3.

## Table 3: Vehicle classes (NRCan, 2015a)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Class</th>
<th>Interior volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>Subcompact</td>
<td>2405-2830 L (85-99 ft³)</td>
</tr>
<tr>
<td>C</td>
<td>Compact</td>
<td>2830-3115 L (110-119 ft³)</td>
</tr>
<tr>
<td>M</td>
<td>Mid-size</td>
<td>3115-3400 L (110-119 ft³)</td>
</tr>
<tr>
<td>L</td>
<td>Full-size</td>
<td>3400 L (120 ft³) or more</td>
</tr>
</tbody>
</table>

All of the data is subject to NRCan’s long-standing disclaimer, “Your fuel consumption will vary”.

### 2.3.1 Conventional Vehicles

Not surprisingly, there are over 1000 CVs listed in the Fuel Consumption Guide. Of these, the Mitsubishi Mirage was chosen as it offers the best fuel consumption ratings for all compact class CVs (see Table 4). At the request of the reviewers (S. Pushkarna, personal communication, 15

---

2 With respect to availability, it is assumed that all vehicles in a category are available (that is, they can be purchased in Canada) and that unless otherwise indicated, the necessary supply of gasoline or electricity is available.
September 2016), the most registered CV in Nova Scotia, the 4-door Honda Civic Sedan, is also included in the comparisons.

Table 4: Best-in-category CV (NRCan, 2015a)\(^3\) and most registered in Nova Scotia\(^4\)

<table>
<thead>
<tr>
<th>Make-Model</th>
<th>Class</th>
<th>Rank in class</th>
<th>City</th>
<th>Highway</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitsubishi Mirage</td>
<td>C</td>
<td>5(^{th})</td>
<td>6.4</td>
<td>5.3</td>
<td>5.9</td>
</tr>
<tr>
<td>Honda Civic</td>
<td>C</td>
<td>18(^{th}) (tied)</td>
<td>7.9</td>
<td>6.1</td>
<td>7.1</td>
</tr>
</tbody>
</table>

2.3.2 Hybrid Electric Vehicles

NRCan ranks HEVs and CVs together in the Fuel Consumption Guide as both categories are considered liquid-fueled vehicles. The Toyota Prius is the best liquid-fueled vehicle, regardless of category (i.e., CV or HEV); its fuel consumption ratings are listed in Table 5.

Table 5: Best-in-category HEV (NRCan, 2015a)

<table>
<thead>
<tr>
<th>Make-Model</th>
<th>Class</th>
<th>City</th>
<th>Highway</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota Prius</td>
<td>M</td>
<td>4.6</td>
<td>4.9</td>
<td>4.7</td>
</tr>
</tbody>
</table>

2.3.3 Plug-in hybrid

The Fuel Consumption Guide lists nine vehicles in its PHEV category. Of these, two stand out because of their different approaches to operating as a plug-in hybrid (see Table 6): the BMW i3 REX (Range-Extender) is the best-in-category in terms of its combined-electric intensity (17.9 kWh/100km) and its electric-only distance (116 km), while the Toyota Prius Plug-in is the best-in-category with respect to its consumption of gasoline (4.7 L/100km), although it has the lowest-in-category electric-only range (17 km). The BMW i3 REX is essentially a BEV with hybrid capabilities added,\(^5\) whereas the Toyota Prius Plug-in operates as a hybrid with plug-in capabilities.

Table 6: Best-in-category PHEVs (NRCan, 2015a)

<table>
<thead>
<tr>
<th>Make-Model</th>
<th>Class</th>
<th>Motor (kw)</th>
<th>City</th>
<th>Highway</th>
<th>Combined</th>
<th>Combined (Electric)</th>
<th>Elec. km</th>
<th>Fuel km</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMW i3 REX</td>
<td>S</td>
<td>125</td>
<td>5.7</td>
<td>6.3</td>
<td>6.0</td>
<td>17.9</td>
<td>0.0</td>
<td>116</td>
</tr>
<tr>
<td>Toyota Prius Plug-in</td>
<td>M</td>
<td>60</td>
<td>4.7</td>
<td>4.8</td>
<td>4.7</td>
<td>18.0</td>
<td>0.4</td>
<td>17</td>
</tr>
</tbody>
</table>

While the 2015 Fuel Consumption Guide PHEV data lists the gasoline consumption for city, highway, and combined driving conditions (L/100km), it gives only the electric intensity for combined driving conditions (kWh/100km).

---

\(^3\) The highest-ranked Compact CV class vehicles were all HEVs (positions 1 through 4).

\(^4\) Based on data supplied by Nova Scotia Power (R. Paruch, personal communication, 14 October 2016).

\(^5\) Vehicles such as the BMW i3 REX can be classified as REEVs or Range Extended Electric Vehicles (REEV, n.d.).
Unless otherwise indicated, any references to PHEV in the analysis refers to the BMW i3 REX.

2.3.4 Battery Electric Vehicles

NRCan lists 12 battery-electric vehicles in its 2015 Fuel Consumption Guide. Although the most widely known BEVs are probably the Nissan Leaf and various Tesla models, the best-in-category is the sub-compact BMW i3, the battery-electric version of the BMW i3 REX (see Table 7).

Table 7: BEVs (NRCan, 2015a)

<table>
<thead>
<tr>
<th>Make-Model</th>
<th>Class</th>
<th>Motor (kW)</th>
<th>City (kWh/100km)</th>
<th>Highway (kWh/100km)</th>
<th>Combined (kWh/100km)</th>
<th>Range (km)</th>
<th>Recharge (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMW i3</td>
<td>S</td>
<td>125</td>
<td>15.2</td>
<td>18.8</td>
<td>16.8</td>
<td>130</td>
<td>4</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>M</td>
<td>80</td>
<td>16.5</td>
<td>20.8</td>
<td>18.4</td>
<td>135</td>
<td>5</td>
</tr>
<tr>
<td>Tesla Model S</td>
<td>L</td>
<td>283</td>
<td>23.9</td>
<td>23.2</td>
<td>23.6</td>
<td>426</td>
<td>12</td>
</tr>
</tbody>
</table>

The analysis considers both the BMW i3 and Nissan Leaf.

2.4 Nova Scotia – background and motor vehicle information

2.4.1 Background

Nova Scotia is Canada’s second smallest province with an area of 55,283 km². It has a population of about 940,000 (Statistics Canada, 2014a); given its ageing population and limited net migration, most population projections expect little or no population growth over the next 20 years (The Daily, 2014).

In 2012, Nova Scotia had the third lowest median family income ($70,020) of any province or territory in Canada; the national median family income was $76,550 (Statistics Canada, 2015a).

2.4.2 Motor vehicles

In 2013, there was a total of 615,561 road motor vehicle registrations in Nova Scotia (Statistics Canada, 2015c); of these, over 93% had a curb-weight of less than 4,500 kg and are classified as cars or light trucks (NRCan, 2015a; Statistics Canada, 2015c).

The average distance travelled in 2012 by a vehicle in Nova Scotia was estimated to be 22,100 km (NRCan, 2015d). Motor gasoline met almost 93% of the energy used for passenger road transportation, while diesel and ethanol were responsible for almost 4% and slightly over 3%, respectively (NRCan, 2015c).

In the 2010 census, of the 355,265 Nova Scotians who identified themselves as commuters, 83.8% relied on cars, trucks, or vans (either as the driver or as a passenger), while 15.1% used sustainable transportation (i.e., public transit and active transportation). Of the 297,800 commuting by car, truck, or van, 269,975 were drivers (Statistics Canada, 2013).

---

6 Census families include couple families, with or without children, and lone-parent families (Statistics Canada, 2015a).

7 NRCan defines light trucks as pickup trucks (small - less than 2,722 kg and standard - 2,722-3,856 kg), sport utility vehicles (small: less than 2,722 kg and standard: 2,722-4,536 kg), minivan (less than 3,856 kg), van (cargo: less than 3,856 kg and passenger: less than 4,536 kg), and special purpose vehicles (less than 3,856 kg) (NRCan, 2015a).
The straight-line distance travelled by those relying on a car, truck, or van in Nova Scotia is shown in Figure 1. Over 37% of commuters had a straight-line of between 7 km and 20 km, while almost 17% had a straight-line distance more than 25 km.

<table>
<thead>
<tr>
<th>One-way, straight-line commute length</th>
<th>Number of commuters</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 35 km (10.4%)</td>
<td></td>
</tr>
<tr>
<td>30 km to &lt; 35 km (2.3%)</td>
<td></td>
</tr>
<tr>
<td>25 km to &lt; 30 km (3.9%)</td>
<td></td>
</tr>
<tr>
<td>20 km to &lt; 25 km (7.2%)</td>
<td></td>
</tr>
<tr>
<td>15 km to &lt; 20 km (11.2%)</td>
<td></td>
</tr>
<tr>
<td>10 km to &lt; 15 km (14.3%)</td>
<td></td>
</tr>
<tr>
<td>7 km to &lt; 10 km (11.6%)</td>
<td></td>
</tr>
<tr>
<td>5 km to &lt; 7 km (9.7%)</td>
<td></td>
</tr>
<tr>
<td>3 km to &lt; 5 km (11.5%)</td>
<td></td>
</tr>
<tr>
<td>1 km to &lt; 3 km (13.2%)</td>
<td></td>
</tr>
<tr>
<td>&lt;1 km (4.7%)</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1: Number of car, truck, or van commuters in Nova Scotia by straight-line distance**  
Percentages denote percent of total commuters (Statistics Canada, 2013)

The typical round-trip distance is assumed to be 30% more than twice the straight-line distance; for example, the estimated round-trip distance for the 10 km to 15 km straight-line distance grouping is in the range of 26 km to 39 km, while almost one-quarter of Nova Scotians had an estimated round-trip commuting distance of at least 52 km (20 km straight-line distance × 2 × 1.3).

### 2.5 Energy processes and flows

An energy system consists of processes organized into chains from an energy source to an energy service. A process, such as in Figure 2, attempts to meet a request for energy from a downstream process or service (a Demand\textsubscript{IN} flow) by processing a flow of energy from an upstream process or energy source (an Energy\textsubscript{IN} flow); the process will interact with its environment (the Environment\textsubscript{IN} and Environment\textsubscript{OUT} flows).

---

8 The average distance travelled is estimated to be 30% longer than the straight-line distance (Hughes & Sundaram, 2011).
A gasoline engine or electric motor are examples of processes. A $\text{Demand}_{\text{IN}}$ flow to an engine or motor is the driver’s demand to travel a certain distance, while the $\text{Energy}_{\text{OUT}}$ flow is the kinetic energy produced to move the vehicle over the required distance.

Each $\text{Energy}_{\text{OUT}}$ flow is associated with a unit-energy cost such as dollars-per-litre or cents-per-kilowatt-hour. The cost of this flow is determined by the cost of the process and its $\text{Energy}_{\text{IN}}$ flows. Each upstream process in the chain contributes to the cost of the $\text{Energy}_{\text{OUT}}$ flow.

A gasoline engine consumes gasoline, its $\text{Energy}_{\text{IN}}$ flow, to meet $\text{Demand}_{\text{IN}}$, in doing so, also produces heat and greenhouse gases that are released to the environment ($\text{Environment}_{\text{OUT}}$).

Although an electric motor consumes electricity without the emissions associated with a gasoline engine, the electricity itself may have been produced by upstream processes with carbon-intensive fuels such as coal, refined oil, or natural gas. Any emissions or other environmental impacts upstream of the electricity generator or the refinery gate are not considered in this report.

Changes to a process’s different flows can affect the energy security of the process or the upstream and downstream processes in its chain (Hughes & Ranjan, 2013). These changes can be discussed in terms of availability, affordability, and acceptability.

3 Availability

Availability is the ability of a process to meet its energy demands. In the case of an electric vehicle, availability involves a process (i.e., an electric motor) converting an $\text{Energy}_{\text{IN}}$ flow (electricity stored in a battery) into the $\text{Energy}_{\text{OUT}}$ flow (i.e., motive or kinetic energy) required to move the vehicle from the place of origin to the intended destination. If an event occurs that makes the vehicle inoperable or one that limits the $\text{Energy}_{\text{IN}}$ flow, making it difficult or impossible to meet the driver’s transportation requirements, then an availability event is said to have occurred (Hughes & Ranjan, 2013).

If the vehicle is maintained properly, then the vehicle operator’s concern is exhausting the vehicle’s battery before the destination can be reached (this applies equally to PHEVs with an empty fuel tank or BEVs). This is referred to as range anxiety. This section presents some examples of causes of range anxiety: temperature and the use of auxiliary services; the availability of infrastructure; and uncoordinated load caused by simultaneous charging.

3.1 Temperature

Electric vehicles are sensitive to temperature for at least two reasons.
First, the Li-ion (lithium ion) batteries used in electric vehicles are affected by temperature extremes, making charging more difficult in cold weather and degrading the lithium in high temperatures (Pesaran, Santhanagopalan, & Kim, 2013). This can add to the cost of the vehicle by reducing the battery’s expected lifetime and, in some extreme cases, result in battery fires (Pesaran, Santhanagopalan, & Kim, 2013).

Second, the range of a BEV decreases when operating in sub-zero temperatures, in part because of a decline in battery efficiency but also with the use of auxiliary services, notably cabin heating. In vehicle-laboratory tests, Transport Canada found that BEV range was reduced by about 25% at -7°C if cabin heating was used (compared with operating the vehicle at -7°C with no heating), while at -18°C, the use of maximum cabin heating reduced vehicle range by more than 50% compared with operating the vehicle at 20°C with no heating or cooling (Meyer, Whittal, Christenson, & Loiselle-Lapointe, 2012). The cold weather was also found to affect battery capacity, reducing it by 4% at -7°C to about 8% at -18°C (compared to 20°C).

The potential effects of cold weather on a BEV with a 130 km range per full-charge are shown in Figure 3. For example, about two-and-a-half 50-km trips could be made on a single full-charge during the summer months; this would be expected to fall to just under two trips when driving at -7°C and about 1.3 trips at -18°C.

![Figure 3: Expected number of possible trips with a fully charged BEV (summer at 20°C and winter at -7°C and -18°C)](image)

Vehicle-data collected by FleetCarma from on-board sensors in Nissan Leafs and Chevrolet Volts corroborate the vehicle-laboratory test results (FleetCarma, 2014). In Figure 4, the relationship between temperature and the expected available-range for the Leaf is shown based on over 7,300 trips; the data does not indicate whether the vehicle was using cabin heat, the state of the vehicle, the road conditions, or the distance driven.
Figure 4: Range vs Temperature for Nissan Leaf (BEV) and Chevrolet Volt (PHEV) (FleetCarma, 2014)

Figure 5 shows how the reliance on cabin heating increases the auxiliary power load as the temperature drops.

Figure 5: Average Auxiliary Power Load vs. Temperature for Nissan Leaf and Chevrolet Volt (FleetCarma, 2014)

3.1.1 Nova Scotia: Winter driving

Despite being nearly surrounded water, Nova Scotia typically experiences four months of the year (January, February, March, and December), with below-zero temperatures (Canada, 2015b). As an example, Figure 6 shows the hourly temperatures observed at Halifax Stanfield International Airport from 1 January 2015 through 31 March 2015.
During the months of January through March in Nova Scotia, it is reasonable to expect that extended periods of sub-zero temperatures will both reduce the maximum distance an electric vehicle can travel (as shown in Figure 3) and increase the demand for electricity (Yuksel & Michalek, 2015).

The reduction in possible distance travelled between January and March can be expected to affect all drivers of electric vehicles; however, since BEVs are typically used for commuting (Botsford, 2015), the most significant impact will be on those with sizeable commutes. Table 8 shows the commuting distances between Halifax and a variety of locations (both within Halifax and nearby communities); it is the actual distance, measured from the center of each jurisdiction, and does not include any vehicle activity within the jurisdiction. Each commuting distance is well within the advertised ranges of the BMW i3 and Nissan Leaf of about 130 km for a fully-charged vehicle (see Table 7). At 20°C, all vehicles, if fully charged, would have sufficient charge to travel the different commuting distances. The return trip would require most vehicles to be recharged; commuters from Windsor and Chester might recharge their vehicles despite the distance requiring about half a battery’s charge (see Table 8).
Table 8: One-way commuting distances between Halifax and selected locations
(Distance Canada, n.d.)

<table>
<thead>
<tr>
<th>To/from Halifax</th>
<th>One-way distance (km)</th>
<th>Number of charges required to complete journey</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20°C 130 km -7°C 97 km -18°C 65 km</td>
</tr>
<tr>
<td>Young and Novalea</td>
<td>2.5</td>
<td>1 1 1</td>
</tr>
<tr>
<td>Beechville</td>
<td>10</td>
<td>1 1 1</td>
</tr>
<tr>
<td>Bedford</td>
<td>17</td>
<td>1 1 1</td>
</tr>
<tr>
<td>Elmsdale</td>
<td>42</td>
<td>1 1 1</td>
</tr>
<tr>
<td>Windsor</td>
<td>66</td>
<td>1 1 2</td>
</tr>
<tr>
<td>Chester</td>
<td>67</td>
<td>1 1 2</td>
</tr>
<tr>
<td>Mahone Bay</td>
<td>87</td>
<td>1 1 2</td>
</tr>
<tr>
<td>Truro</td>
<td>94</td>
<td>1 1 2</td>
</tr>
<tr>
<td>Kentville</td>
<td>105</td>
<td>1 2 2</td>
</tr>
<tr>
<td>Bridgewater</td>
<td>105</td>
<td>1 2 2</td>
</tr>
<tr>
<td>Sheet Harbour</td>
<td>114</td>
<td>1 2 2</td>
</tr>
</tbody>
</table>

If these vehicles were driven in -7°C conditions with cabin heating on, the advertised range could be expected to decline about 25% to about 98 km, meaning that trips to or from Kentville (105 km), Bridgewater (105 km), or Sheet Harbour (114 km) would probably require a charge during the commute in order to reach the destination. In more extreme conditions of -18°C, all vehicles driven from beyond Elmsdale would probably require a charge during the commute.

The need to increase the frequency of charging will be required for all in-use electric vehicles during periods of extreme cold whether or not they use cabin-heating, regardless of the distance travelled. This may have other implications; for example:

- The additional demand for electricity for charging BEVs would occur during the time of year when Nova Scotia Power faces its greatest demand for electricity. The additional demand could occur at any time throughout the day and night.
- Pre-heating the vehicle and battery may reduce the need for cabin-heating in some short-distance journeys and reduce the effect of low temperatures on the batteries; however, this will increase demand for electricity before the journey.
- There will be a demand for additional charging stations in shared parking lots, both public and private, to allow all vehicles to recharge for the next part of their journey.
- Long-distance commuters may be forced to add considerable time to their journey if required to wait for other commuters to charge their vehicles at road-side charging stations.

9 The impact of cold-weather driving is based on the report by Meyer et al. (2012) for Transport Canada as opposed to that shown for the Nissan Leaf in Figure 4. This decision was taken because the results in Figure 4 give no indication as to the trip length, cabin conditions, road conditions, or the age of the battery, whereas those found in the Transport Canada report are under controlled, repeatable conditions.
### 3.2 Charging infrastructure

All vehicles, both electric and gasoline, require a readily available source of energy. Gasoline vehicles (CVs, HEVs, and PHEVs) all have the advantage of a well-established network of fuel stations throughout the province. On the other hand, BEVs can be recharged only where there is a mains outlet, such as a residence, charging stations, and public and private parking lots that offer spaces to charge them.

There are a number of different types of Electric Vehicle Supply Equipment (EVSE or simply chargers (Berman, 2014a)) on the market. In Table 9, five different types of chargers are listed, from low-cost, slow-charge units intended for residential use (AC Level 1) to high-cost, fast-charge units designed to operate in commercial conditions (DC Level 2). The installed price includes the cost of the charger, materials, labour (electrician and other), transformer (DC charging only), and permitting (Agenbroad & Holland, 2014).

**Table 9: Types and characteristics of Electric Vehicle Supply Equipment (Bohn, 2013)**

*Prices in U.S. dollars (from (Agenbroad & Holland, 2014))*

<table>
<thead>
<tr>
<th>Charging Level</th>
<th>Setting</th>
<th>Power supply</th>
<th>Rating (typical)</th>
<th>Installed price</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Level 1</td>
<td>Residential or Parking lot</td>
<td>120VAC/20A (16A continuous)</td>
<td>1.7 kW</td>
<td>$650-$1,800</td>
</tr>
<tr>
<td>AC Level 2</td>
<td>Residential or Parking lot</td>
<td>208/240VAC/20A (16A continuous)</td>
<td>3.4 kW</td>
<td>$3,550-$7,500</td>
</tr>
<tr>
<td>AC Level 2</td>
<td>Commercial</td>
<td>208/240VAC/100A (80A continuous)</td>
<td>19.2 kW</td>
<td>$5,300-$13,150</td>
</tr>
<tr>
<td>DC Level 1</td>
<td>Commercial</td>
<td>208/480VAC ~20A-200A AC</td>
<td>40 kW</td>
<td>$29,650-$80,400</td>
</tr>
<tr>
<td>DC Level 2</td>
<td>Commercial</td>
<td>208vac/480VAC ~20A-400A AC</td>
<td>100 kW</td>
<td></td>
</tr>
</tbody>
</table>

The time taken to recharge a vehicle depends on the state of the battery when the charge begins and its capacity. For example, the BMW i3’s battery (18.8 kWh capacity) can be charged to 80% capacity in less than 30 minutes using a DC charger (50 kW) or between 6 to 8 hours with an AC charger (1.9 kW to 2.5 kW) (BMW, n.d.).

Although a BEV can be charged anywhere there is an available supply of electricity, the time required to recharge is often done where the vehicle is idle for lengthy periods of time, such as at the owner’s residence or place of work. This requires the installation of EVSEs at either or both of these locations:

- If the BEV is not supplied with an EVSE or the EVSE is considered inadequate for the application, the user will be responsible for purchasing and installing the EVSE (Berman, 2014a). This will add to the overall cost of the vehicle.

- Owners of a BEV who park their vehicle on the street (as opposed to in a garage or private driveway) would need either to run a charging cable from their home to the vehicle or to install
a curbside EVSE. Vehicles parked beyond the range of the charging cable or curbside EVSE would require access to other charging infrastructure.

- EVSEs installed in public and private parking-lots could be expected to experience greatest demand during periods of sub-zero temperature driving-conditions. If the parking lot had insufficient chargers, it would be necessary to coordinate the recharging of the vehicles throughout the day.

- The cost of recharging in a parking lot would be a function of the total number of vehicles charged in a year, the cost of purchasing and installing the EVSE, and the cost of electricity over the lifetime of the charger. This would also affect the time required to recoup the cost of the charging facilities. Without the promise of sufficient revenue, the parking-lot owner may decide not to install any charging facilities, install a less-expense charger with a lower-rate (meaning fewer vehicles could be charged during periods of peak demand), or install a single high-rate charger (requiring some form of coordinated charging).

3.3 Electricity supply

3.3.1 Uncoordinated charging

The substantial addition of load to any distribution grid can impact the grid’s demand profile, voltage profile, and voltage unbalance. Results from numerous simulations have demonstrated that the negative effects of electric vehicles (i.e., both BEV and PHEV) integration were particularly significant in systems without coordinated charging (see section 3.3.2):

Demand Profile. With respect to demand profile, literature suggests that the biggest impact will be seen at the distribution transformer level (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012). Further, across all simulations, uncoordinated charging led to significant increases in daily peak energy consumption, as EV owners were simulated charging their vehicles when reaching home (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012; Tuan, Le Pivert, Saheli, & Beaude, 2012; Leemput, Van-Roy, Olivella-Rosell, Driesen, & Sumper, 2015). Additionally, the increased load, even if off-peak, could result in decreased equipment life, particularly given the relationship between transformer temperature and insulation degradation.

By simulating the connection of up to six electric vehicles on a 25 kVA distribution transformer serving six households, significant decreases in equipment life in instances of uncoordinated charging were demonstrated (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012). The worst case scenario studied was simultaneous charging of all vehicles at 7pm, when the extra load associated with the EVs was coincident with peak load, significantly increasing the temperature of the transformer, resulting in insulation life of less than six months, compared with the normal 20.5 year operating lifespan (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012). The report concluded that the impact on transformer life could be mitigated through the use of smart metering and coordinated charging (Gong, Midlam-Mohler, Marano, & Rizzoni, 2012).

Voltage Profile. Here, voltage profile refers to the magnitude of voltage seen at the residential load. For safe operation of appliances and electronics, utilities typically adhere to an electricity supplier’s voltage-magnitude standard (for example, see (Hydro Quebec, 2015)). This standard
requires provision of electricity within a bandwidth of voltages considered acceptable for end-use committing to minimum and maximum voltages within the tolerances of end-use devices. Operation outside of these parameters can cause unsafe operating conditions and result in significant appliance damage.

The simulation of a rural distribution grid with ten electric vehicles connected to individual household chargers (i.e., slow charging) and six electric vehicles connected to public charging-stations (i.e., fast charging) resulted in sustained (i.e., three hours) voltages of less than 95% of recommended voltages during uncoordinated on-peak charging in the distribution grid (Tuan, Le Pivert, Saheli, & Beaude, 2012). The results were corroborated in a simulation where uncoordinated charging resulted in worst-case voltages of less than 75% and typically observed voltages less than 85% of recommended voltages throughout the simulation, affecting each of the simulated households (Leemput, Van-Roy, Olivella-Rosell, Driesen, & Sumper, 2015).

**Voltage Unbalance.** Voltage unbalance refers to differences in voltage magnitude across the phases of a system. In a distribution system, voltage unbalance can be the result of uneven distribution of charging single-phase loads within the system (i.e. connecting and disconnecting a number of electric vehicles served by a single-phase circuit).

The simulation of a 400 kVA feeder with 39 residential single-phase households saw distribution transformer load doubling and grid losses quadrupling when the penetration of electric vehicles reached 100% (i.e., one plug-in vehicle per household) (Leemput, Van-Roy, Olivella-Rosell, Driesen, & Sumper, 2015). If significant numbers of EVs were concentrated on a single phase in a distribution system, the associated large intermittent load could result in voltage unbalance conditions within the system (Bishop, 2008).

### 3.3.2 Coordinated charging

Electricity suppliers’ attempt to meet demand at the lowest possible cost. A challenge facing many suppliers is how to meet demand during peak hours as this typically involves the production of electricity at a high cost. If the demand can be shifted to non-peak hours, the supplier still meets the same demand, but with low-cost electricity. The addition of electric vehicles to the system’s load raises other challenges; for example:

- If consumers attempt to charge their vehicles concurrently during, for example, the evening peak, there can be an additional demand on the electricity system.

- If several consumers need to charge their vehicles during working hours in, for example, a building’s garage that has a single EVSE, some customers may be unable to charge their vehicles, forcing the electricity supplier or the building’s owner to increase the number of EVSEs. (Some building codes encourage the installation of parking spaces for electric vehicles; for example, LEED awards 1 point to buildings that designate 5% of their parking for electric vehicles (LEED, 2016).)

If the electricity supplier is to achieve its objective of meeting demand at the lowest possible cost, some form of control is required over the charging of the vehicles. While it is possible for customers to coordinate actions between themselves (for example, when a person’s vehicle is
charged, the next person in the queue is informed so that their vehicle can be charged), such actions are prone to mistakes or oversights. Such a solution is not easily achievable if individual consumers attempt to charge their vehicles at home.

Rather than relying on the consumer to coordinate charging, the widespread availability of information and communications technology (ICT) embedded in many everyday items (such as electric vehicles and EVSEs) enables electricity suppliers to control the costs of meeting demand. For example, an EVSE with multiple connections could allow several vehicles to connect to it at once at a known maximum demand. There are a variety of possible ways to charge the vehicles; for example:

- Vehicles can be charged in a first-come, first-served manner. When the vehicle currently being charged indicates that it has achieved full charge, the ESVE can switch to the next in the queue. While this eliminates the need for human coordination, it has the potential to shutout some vehicles.

- Vehicles can be charged in a round-robin or time-shared fashion, in which each is charged for a specific interval (say five minutes) and then the next vehicle is charged. As vehicles reach full charge, the time available for charging the remaining vehicles increases.

- Priority charging could be supported for vehicles that must be charged within a given period. In these cases, the EVSE could devote more charging time to the vehicle and increase the cost of electricity for this service.

The above methods could be achieved using a “smart” EVSE without requiring changes to the electricity supplier.

A variation on the aforementioned charging methods would be needed by an electricity supplier in order to coordinate charging during peak hours. However, in these cases, the coordination of the charging would be handled by the electricity supplier, in conjunction with each EVSE. This requires a communication link between the supplier and each EVSE. For example, before starting the charging process, the EVSE could signal the supplier with an indication of the number of kilowatt-hours required, the time when a full-charge is required, and the maximum the driver would be willing to pay for the charging. From this information, the supplier could schedule when the charging would begin and the volume of electricity required to meet the demand.

Such approaches to charging vehicles is sometimes referred to as “smart charging” and is often part of a home energy management system (HEMS) and its smart-meter. Not surprisingly, a “smart grid” carrying both electricity and data (for communications with the HEMS or EVSE, or possibly both) must be supported by the electricity supplier. The electricity supplier would, in turn, manage the entire system.

3.4 Nova Scotia

An increase in the number of electric vehicles in Nova Scotia would, at first glance, be an attractive proposition to Nova Scotia Power as it would be a way of increasing its revenues.

---

10 In these examples, it is assumed that customers identify themselves to the EVSE using, for example, a credit card, which is then billed for the electricity supplied.
However, there will be issues that need to be addressed by NSP. Given a sufficiently large uptake in electric vehicles, the potential grid impacts, including changes to demand profile, voltage profile, and voltage unbalance could have significant impact in Nova Scotia, particularly with its large rural population and the associated rural distribution grids, including the 69 kV transmission grid in the south-western area of the province.

The effects of charging electric vehicles on the provincial grid would depend on the number of vehicles being charged, the charge rate, and when the charging took place. For example, Table 10 shows the effect of adding between 10 and 100,000 electric vehicle EVSEs (typically rated between 3.3 kW to 6.6 kW (PlugInCars, 2015)) to the grid – the maximum hourly demand would range between 33 kW to 660 MW. Adding an additional 660 MW of load to the grid during the evening peak could be a challenge, especially during the winter months.

<table>
<thead>
<tr>
<th>Number of vehicles</th>
<th>Hourly demand (MW)</th>
<th>3.3 kW charge rate</th>
<th>6.6 kW charge rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.033</td>
<td>0.066</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0.3</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>3.3</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td>10,000</td>
<td>33</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>100,000</td>
<td>330</td>
<td>660</td>
<td></td>
</tr>
</tbody>
</table>

### 4 Affordability

In the context of this report, affordability refers to payment for the cost of driving within the limits of a budget (Hughes & Ranjan, 2013).

The cost of driving can be discussed in a number of different ways. Perhaps the most common is to consider the energy required to drive 100 km, usually expressed litres-per-100 km (L/100km) for liquid fuels or kilowatt-hour-per-100 km (kWh/100km) for electricity. The total cost is determined by the price of the fuel set by the energy supplier, any taxes assigned by regulatory bodies, the distance driven, and the vehicle’s fuel consumption over the distance.

Another approach is to take the annual operating costs (including the cost of fuel) and the lifetime cost of the vehicle into consideration.

#### 4.1 Energy cost per 100 kilometre

The cost of driving depends on numerous factors, including the distance travelled, the unit energy cost, the way the vehicle is driven, and the state of the vehicle. To illustrate this, the effects of fuel price and vehicle efficiency on the cost of driving a vehicle 100 kilometres are compared for an electric vehicle (a BEV or a PHEV) and an internal combustion vehicle (a CV, HEV, or a PHEV).

For the purposes of this example, the energy costs considered are $0.10/kWh, $0.20/kWh, and $0.30/kWh for electricity and $0.90/L, $1.10/L, and $1.30/L for petroleum fuels. The efficiencies considered are 15 kWh/100km and 25 kWh/100km for EVs and 4.5 L/100km and 12.5 L/100km. The comparison is shown in Figure 7.
Figure 7: Comparison of efficiency and cost scenarios for driving 100 km in a BEV or CV

For example, driving a BEV a distance of 100 km at $0.20/kWh would cost between $3.00 (15 kWh/100km efficiency, solid orange circle) and $5.00 (25 kWh/100km efficiency, orange outline of circle), whereas driving a CV at $1.10/L over the same distance would cost between $4.95 (4.5 L/100km efficiency, solid dark-blue square) and $13.75 (12.5 L/100km efficiency, dark-blue outline of square). With the exception of driving an efficient CV at $0.90/L, the energy cost of an efficient BEV is always less than a CV, while inefficient BEVs are always less expensive to operate than an inefficient CV.

The overall per-kilometre cost may be influenced by other factors, including:

**Time-of-use pricing.** The cost of electricity may vary throughout the day, meaning that the total cost of the electricity used by the vehicle may not be constant as suggested in Figure 7.

**Auxiliary services.** The total electricity required for the trip may exceed the expected kWh/km. For example, in cold weather, additional electricity may be required for cabin-heat supplied by the vehicle’s battery or a pre-heated storage-heater.

**Taxes.** The per-kilometre cost of a liquid fuel often includes a road tax; these taxes are typically not collected from users of electric-vehicles, thereby making electric vehicles appear less costly to operate.

### 4.1.1 Nova Scotia

One of the arguments for electric vehicles in Nova Scotia is that they are considerably less expensive to operate than hybrid and conventional vehicles because of the high cost of gasoline. The data used for Figure 8 illustrates this – the cost of the energy needed to drive 100 km in a Nissan Leaf charged at NSP’s residential rate ($0.15694/kWh) is between about three-quarters
to half for the Prius, 60% to 40% for the Mirage, and half to one-third for the Civic, for gasoline prices between $0.90 and $1.30/litre.  

As Table 11 shows, the differences become more apparent when considering the annual fuel costs for driving distances of 10,000 km, 20,000 km, and 30,000 km.

Table 11: Fuel costs for driving various distances (electricity at $0.15694/kWh)

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>BMW i3</th>
<th>Leaf</th>
<th>Prius $0.90</th>
<th>Prius $1.10</th>
<th>Prius $1.30</th>
<th>Mirage $0.90</th>
<th>Mirage $1.10</th>
<th>Mirage $1.30</th>
<th>Civic $0.90</th>
<th>Civic $1.10</th>
<th>Civic $1.30</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>$264</td>
<td>$289</td>
<td>$423</td>
<td>$517</td>
<td>$611</td>
<td>$531</td>
<td>$649</td>
<td>$767</td>
<td>$639</td>
<td>$781</td>
<td>$923</td>
</tr>
<tr>
<td>20,000</td>
<td>$527</td>
<td>$578</td>
<td>$846</td>
<td>$1,034</td>
<td>$1,222</td>
<td>$1,062</td>
<td>$1,298</td>
<td>$1,534</td>
<td>$1,278</td>
<td>$1,562</td>
<td>$1,846</td>
</tr>
<tr>
<td>30,000</td>
<td>$791</td>
<td>$866</td>
<td>$1,269</td>
<td>$1,551</td>
<td>$1,833</td>
<td>$1,593</td>
<td>$1,947</td>
<td>$2,301</td>
<td>$1,917</td>
<td>$2,343</td>
<td>$2,769</td>
</tr>
</tbody>
</table>

4.2 Annualized costs

The annualized cost attempts to capture the total, annual cost of owning and operating a vehicle by tallying annual expenses such as the cost of fuel, insurance, maintenance, and repayments.  

The base prices for the vehicles considered in this report are shown in Table 12.
Table 12: 2015 vehicle base-prices (prices in Canadian dollars)\textsuperscript{13}

\begin{tabular}{|l|c|}
\hline
Vehicle & Base price \\
\hline Mitsubishi Mirage & $13,948 \\
Honda Civic & $15,833 \\
Toyota Prius & $26,305 \\
Nissan Leaf & $31,998 \\
Toyota Prius Plug-in & $35,905 \\
BMW i3 BEV & $44,950 \\
BMW i3 REX & $48,950 \\
\hline
\end{tabular}

Figure 9 shows the annualized repayment and fuel costs for each vehicle, assuming the vehicle is purchased at the base-price with an interest rate of 2\%, driven the Nova Scotian average of 22,100 km a year (NRCan, 2015d) for five years with a 55\% city and 45\% highway split, and at a cost of $0.15/kWh and $1.10/litre. As the annualized costs decline, the cost of energy becomes more significant; for example, about 5.7\% of the BMW i3 BEV’s cost is for fuel (electricity), whereas it is about 34\% and 33\% of the total cost of the Civic and Mirage, respectively. Despite this advantage, the Mirage’s annualized cost is about half that of the BMW i3 because of its lower purchase price.

\textbf{Figure 9: A comparison of annualized vehicle costs (BMW i3 Rex: using either gasoline or electric only)}

Between January 2010 and March 2015, the average monthly sales of passenger cars and trucks in Nova Scotia were split almost equally, while the average price paid for a truck (which includes

\textsuperscript{13} The Honda Civic base price is for 2016.
minivans, sports-utility vehicles, and light trucks) was almost $12,000 more than for a passenger car (see Table 13).

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Vehicles sold per month</th>
<th>Average price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger cars</td>
<td>2,079</td>
<td>$24,188</td>
</tr>
<tr>
<td>Trucks</td>
<td>2,009</td>
<td>$35,874</td>
</tr>
</tbody>
</table>

Table 13: Average monthly new vehicle sales and price in Nova Scotia (January 2010 to March 2015) (Statistics Canada, 2015b)

Assuming the same parameters as those used in Figure 9, if a Mirage or a Civic had been purchased for $24,188, the annualized cost would be $5,132, which is about $1,600 less than the annualized cost of the Leaf at $6,789. However, even if the Leaf could be purchased for its base price of $31,998, the difference in base prices would be about $7,800, potentially deterring some buyers.

4.3 Road taxes

The affordability of electricity is a commonly used argument for driving an electric vehicle rather than a conventional one (for example, see (Campbell, 2015; Calvi, 2015)). However, simply comparing the cost of electricity and the cost of gasoline is misleading since the cost of gasoline typically includes a number of road-related taxes which are not applied to electricity. This means, amongst other things, that in many jurisdictions BEVs do not pay for their usage of the road network.

The subject of the collection of road taxes and electric vehicles is discussed further in section 6.4.

4.3.1 Nova Scotia

In Nova Scotia, vehicles using liquid fuels are subject to three levels of taxation: a provincial gasoline fuel tax (a flat rate of $0.155/L) (Access Nova Scotia, 2015), a federal excise tax on gasoline (a flat rate of $0.10/L) (NRCan, 2014), and the 15% Harmonized Sales Tax (HST), which is applied to both the gasoline and the taxes (Finance and Treasury Board, 2015). The provincial gasoline tax is used for the construction and maintenance of highways (Finance, 2010), while roughly half of the federal excise tax is dedicated to funding projects in municipalities (Infrastructure Canada, 2013; Infrastructure Canada, 2014).

If these taxes were removed, the price of gasoline would fall considerably, as shown in Table 14. The rightmost column is the price of gasoline without taxes, the three middle columns are the applicable taxes (the federal gasoline excise tax and provincial gasoline tax) and the HST (applied to the price of gasoline and the federal and provincial taxes), while the leftmost column is the pump-price of the gasoline. At $0.90/litre, about 41% of the cost of gasoline is for taxes, whereas at $1.30/litre, taxes account for about one-third of the price.

---

14 Trucks include minivans, sports-utility vehicles, light and heavy trucks, vans, and buses.
Table 14: Cost of gasoline with and without taxes

<table>
<thead>
<tr>
<th>Gasoline price with taxes ($/L)</th>
<th>Taxes (per litre)</th>
<th>Gasoline price without taxes ($/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0.90</td>
<td>$0.117</td>
<td>$0.37</td>
</tr>
<tr>
<td>$1.10</td>
<td>$0.143</td>
<td>$0.40</td>
</tr>
<tr>
<td>$1.30</td>
<td>$0.170</td>
<td>$0.42</td>
</tr>
</tbody>
</table>

If these taxes were not applied to gasoline, its price would fall, making the cost of fuel for HEVs and CVs more competitive with that of electricity; the fuel costs associated with driving 100 km under combined-driving conditions are shown in Table 12.

![Figure 10: Price per unit energy and cost of driving 100 km in Nova Scotia without fuel taxes (solid boxes) and with taxes (solid and dashed boxes)](image)

At present, Nova Scotia does not apply any form of road tax to electric vehicles (the 5% HST is not a road tax). As a result, BEVs are able to use Nova Scotia’s road network without charge.

5 Acceptability

For the purpose of this report, acceptability refers to the greenhouse gas emissions associated with driving a vehicle.

5.1 Emissions

NRCan’s 2015 Fuel Consumption Guide lists the greenhouse gas emissions associated with BEVs as zero grams of CO\textsubscript{2}e per kilometre. While there are no greenhouse gas Environment\textsubscript{OUT} flows from the BEV itself, the process of generating electricity does, in many jurisdictions, result in CO\textsubscript{2} Environment\textsubscript{OUT} flows.

The emissions associated with both liquid-fuel and electric vehicles come primarily from the combustion of hydrocarbons. In a liquid-fuel vehicle (CV, HEV, or PHEV), the combustion of
gasoline results in three different greenhouse gases: carbon dioxide, methane, and nitrous oxide (see Table 15); the sum of these emissions is often referred to as CO$_2$e or carbon-dioxide equivalent. An electricity supplier’s emissions intensity (CO$_2$e/kWh) depends upon its energy mix.

Table 15: Greenhouse gases (CO$_2$e) per litre of gasoline (Canada, 2013)

<table>
<thead>
<tr>
<th>Greenhouse gas</th>
<th>kg/L</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (CO$_2$)</td>
<td>2.289</td>
<td>99.993%</td>
</tr>
<tr>
<td>Methane (CH$_4$)</td>
<td>3.20×10^{-4}</td>
<td>0.014%</td>
</tr>
<tr>
<td>Nitrous oxide (N$_2$O)</td>
<td>6.60×10^{-4}</td>
<td>0.029%</td>
</tr>
<tr>
<td>Total (CO$_2$e)</td>
<td>2.2900</td>
<td></td>
</tr>
</tbody>
</table>

Figure 11 shows the greenhouse gas intensity (grams of CO$_2$e per kilometre) associated with the different vehicles. The emissions per kilometre from both the BMW i3 (BEV), Leaf (BEV), and BMW i3 Rex (PHEV running on electricity only) vary from less than 20 g CO$_2$e/km to slightly over 180 g CO$_2$e/km, depending on the greenhouse gas intensity of the electricity supplier (grams of CO$_2$e per kilowatt-hour) and the vehicle’s electricity intensity (kilowatt-hours per kilometre), while the emissions of the BMW i3 Rex (PHEV running on gasoline only), Prius (HEV), Mirage (CV), and Civic (CV) are constant, determined by the vehicle’s fuel intensity (litres per kilometre), regardless of the distance. The emissions associated with BMW Rex using gasoline and the Mirage are almost identical, whereas those of Civic are about 18% higher. Figure 11 refers to combined driving conditions (i.e., 55% city and 45% highway) as NRCan reports the electricity intensity for PHEVs for combined driving only, not city or highway.

The emissions per kilometre from an electric vehicle will vary over a year for a number of reasons, including:
Supplier energy mix. The electricity supplier’s energy mix can vary throughout the day, resulting in different emissions intensities. The emissions intensity of the electricity at the time of charging will be reflected in the vehicle’s emissions.

Auxiliary services. In addition to a vehicle’s motive energy requirements, additional energy may be required for auxiliary services such as cabin heating.

Types of journeys. BEVs can be optimized to operate better in one set of conditions than another. For example, most BEVs listed in the Fuel Consumption Guide have a lower per kilometre electric-intensity for cities than highways; whereas the Tesla vehicles are the opposite (see Table 7).

5.1.1 NSP-specific – changes over next decade

Over the past decade, NSP has made considerable reductions in its greenhouse gas emissions (see Figure 12). The reductions can be attributed to an increase in renewables (especially wind), a greater reliance on natural gas, and a reduction in demand. Additional declines in emissions are expected in 2017 with the replacement of electricity from existing NSP’s coal-fired generating stations with hydroelectricity from Muskrat Falls in Newfoundland and Labrador.\textsuperscript{15} If NSP’s forecasts are correct, emissions in 2015 will be one-third lower than in 2005, a decline from 915 g CO\textsubscript{2}e/kWh to 603 g CO\textsubscript{2}e/kWh. When electricity from Newfoundland and Labrador is supplied to Nova Scotia Power, emissions are expected to be about half of what they were in 2005.

\footnote{Construction delays means that first power from Muskrat Falls, originally forecast for December 2017 (Newfoundland and Labrador, 2015), is now not expected until sometime in 2018 (CBC, 2015).}
Figure 12: NSP’s emissions – actual and forecast
Data sources: 2005-14 NIR (Canada’s National Inventory Report to the IPCC); 2005-14 Actual (NSP’s recently released emissions data); 2010-20 EV Report (forecast emissions from NSP in 2010); 2015-35 Forecast 1 and Forecast 2 (NSP’s long-term forecast to 2039)

5.1.2 Emissions per vehicle
NSP’s average annual emissions are forecast to decline from about 700 g CO$_2$e/kWh in 2014 to about 450 g CO$_2$e/kWh by 2030. Assuming no further technological advances in any of the vehicles considered in this report, this means that electric vehicles will become increasingly more environmentally acceptable than the best conventional and hybrid-electric vehicles, as shown in Figure 13.
5.1.3 Cumulative emissions

A vehicle’s cumulative emissions are the emissions produced over its lifetime while operating. For example, Figure 14 shows the cumulative emissions associated with driving a BMW i3 (BEV), a Leaf (BEV), Prius (HEV), a Mirage (CV), and a Civic (CV) for eight years at 20,000 km a year starting in 2015 in Nova Scotia. During this time, NSP’s forecast emissions fall from 602 g/kWh to 480 g/kWh, while the emissions from the Prius, Mirage, and Civic are assumed to be constant at 108 g/km, 135 g/km, and 163 g/km, respectively. For example, by 2022, the Prius and Mirage would have emitted an additional 3.2 tonnes and 7.7 tonnes of CO₂e compared with the BMW i3, respectively.

![Cumulative emissions](image)

**Figure 14: Cumulative emissions from a BMW i3, Leaf, Prius, Mirage, and Civic driven 20,000 km per year in Nova Scotia (2015-2022)**

Table 16 shows the total emissions from the four different types of vehicle for different distances in Nova Scotia between 2015 and 2022. In all cases, the BMW i3 has the lowest emissions; for example, if a BMW i3 and Prius were driven 10,000 km a year, the different in total emissions would be 1.64 tonnes, whereas a Mirage driven 30,000 km a year would result in about 11.5 tonnes more total cumulative emissions than a BMW i3 driven the same distance over the eight year period.
Table 16: Total cumulative emissions (tonnes) for different distances in Nova Scotia (2015-2022)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Distance driven</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10,000 km</td>
</tr>
<tr>
<td>BMW i3</td>
<td>6.97</td>
</tr>
<tr>
<td>Leaf</td>
<td>7.63</td>
</tr>
<tr>
<td>Prius</td>
<td>8.61</td>
</tr>
<tr>
<td>Mirage</td>
<td>10.81</td>
</tr>
<tr>
<td>Civic</td>
<td>13.01</td>
</tr>
</tbody>
</table>

If the decline in NSP’s emissions continues as projected into the 2020s, these differences would become more pronounced, given the same vehicles (see Table 17). During this time period, a Prius driven 10,000 km would emit 2.05 tonnes more than the BMW i3, while the emissions from a Mirage driven 30,000 km would exceed those of a BMW i3 by about 12.75 tonnes.

Table 17: Total cumulative emissions (tonnes) for different distances in Nova Scotia (2020-2027)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Distances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10,000 km</td>
</tr>
<tr>
<td>BMW i3</td>
<td>6.56</td>
</tr>
<tr>
<td>Leaf</td>
<td>7.17</td>
</tr>
<tr>
<td>Prius</td>
<td>8.61</td>
</tr>
<tr>
<td>Mirage</td>
<td>10.81</td>
</tr>
<tr>
<td>Civic</td>
<td>13.01</td>
</tr>
</tbody>
</table>

While the difference in emissions between PEVs and liquid-fueled CVs is significant, it is worth considering the emissions intensities in the electricity supply in other jurisdictions and how this compares with Nova Scotia. For example, in 2014, Quebec’s electricity system had an emissions intensity of 2.1 g CO$_2$e/kWh, while Ontario’s was 41 g CO$_2$e/kWh (Environment Canada, 2016). This means that driving a Leaf a distance of 100 km (at 18.4 kWh/100km) would result in 0.039 kg CO$_2$e in Quebec, 0.754 kg CO$_2$e in Ontario, and 12.88 kg CO$_2$e in Nova Scotia. This is due entirely to the availability of hydroelectricity in Quebec and hydroelectricity and nuclear in Ontario for the generation of electricity.

6 Discussion

6.1 Electric-vehicle penetration

In 2012, there was an estimated 128.7 million cars in the United States (both conventional-fuel and alternative-fuel) (EIA, 2015). Of the roughly 4.73 million alternative-fuel vehicles, almost 95% were either ethanol flex-fuel vehicles or HEVs, while PHEVs and BEVs made up 1.2% and 0.8%, respectively (see Table 18). In terms of the total number of cars in the United States, BEVs and PHEVs were less than 0.08% of the total. In 2013, about half of the BEVs in the United States were registered in California (EIA, 2014).
Table 18: Alternative-vehicle stock in the United States – Reference scenario (EIA, 2015)
(Millions of vehicles)

<table>
<thead>
<tr>
<th>Car type</th>
<th>2012 (actual)</th>
<th>2020 (estimated)</th>
<th>2030 (estimated)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Percent</td>
<td>Total</td>
</tr>
<tr>
<td>Propane ICE</td>
<td>0.03</td>
<td>0.6%</td>
<td>4.48</td>
</tr>
<tr>
<td>Natural Gas ICE</td>
<td>0.03</td>
<td>0.6%</td>
<td>0.00</td>
</tr>
<tr>
<td>Ethanol-Flex Fuel ICE</td>
<td>2.39</td>
<td>50.6%</td>
<td>4.43</td>
</tr>
<tr>
<td>Plug-in 10 Gasoline Hybrid (PHEV)</td>
<td>0.02</td>
<td>0.4%</td>
<td>0.08</td>
</tr>
<tr>
<td>Plug-in 40 Gasoline Hybrid (PHEV)</td>
<td>0.04</td>
<td>0.8%</td>
<td>0.34</td>
</tr>
<tr>
<td>100-Mile Electric Vehicle (BEV)</td>
<td>0.04</td>
<td>0.8%</td>
<td>0.21</td>
</tr>
<tr>
<td>200-Mile Electric Vehicle (BEV)</td>
<td>0.00</td>
<td>0.0%</td>
<td>0.05</td>
</tr>
<tr>
<td>Electric-Gasoline Hybrid (HEV)</td>
<td>2.09</td>
<td>44.3%</td>
<td>0.16</td>
</tr>
<tr>
<td>Other</td>
<td>0.09</td>
<td>1.9%</td>
<td>0.11</td>
</tr>
<tr>
<td>Total Alternative-Fuel Cars</td>
<td>4.72</td>
<td>100.0%</td>
<td>9.86</td>
</tr>
<tr>
<td>Total car stock</td>
<td>128.66</td>
<td>100.0%</td>
<td>131.68</td>
</tr>
</tbody>
</table>

The EIA’s reference scenario projections to 2020 and 2030 in Table 18 show that the total number of vehicles (both alternative and conventional) will increase, in part because of increased demand for alternative-fuel vehicles. By 2030, the number of BEVs (100 and 200 Mile Electric Vehicles) and PHEVs (Plug-in 40 and Plug-in 10 Gasoline Hybrid Vehicles) will have increased from about 100,000 vehicles in 2012 to almost 1.5 million, most of which are PHEVs. About 1% of the total car stock of 142 million vehicles in 2030 is expected to be BEVs and PHEVs.

6.2 Increasing public acceptance of electric vehicles

At present, there are very few electric vehicles on Nova Scotia’s roads (Pushkarna, 2015). For the numbers to increase, the public’s attitude towards electric vehicles would need to change.

There are five criteria that govern the rate at which innovations, such as the electric vehicle (and like others before it, including electricity, the telephone, and the home computer), are accepted by society (Rogers, 2003; Gourville, 2005):

**Relative advantage** refers to the cost and benefit advantages of the innovative product compared to its existing counterpart – the greater this perception, the greater the relative advantage. The advantages associated with electric vehicles, such as lower greenhouse gas emissions, reduced operating noise, and the convenience of at-home charging, must be indicative of public reaction and perceived net benefit over CVs. Despite these advantages, opinion polls suggest that they are not sufficient to sway the public in their favour.

A survey of 2,171 individuals in Newfoundland and Labrador (see Table 19) found that only 18% would consider purchasing an electric vehicle. Although 28% had concerns regarding range and battery capacity, most respondents (44%) expressed a high level of uncertainty regarding product capabilities and market readiness.

<table>
<thead>
<tr>
<th>Would you ever consider buying an electric vehicle?</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, it’s better for the environment.</td>
<td>18%</td>
</tr>
<tr>
<td>Maybe, if the battery lasted as long as a tank of gas.</td>
<td>28%</td>
</tr>
<tr>
<td>No. Wait until they iron out the bugs.</td>
<td>44%</td>
</tr>
<tr>
<td>I don’t know.</td>
<td>10%</td>
</tr>
</tbody>
</table>

These results are consistent with a Canadian electric vehicle consumer preferences study conducted in 2010 which found that amongst those who indicated a willingness to consider purchasing an electric vehicle, two-thirds would no longer be willing if there was a price premium for electric vehicles (Deloitte, 2011). A further 3% and 5% indicated that the highest premium they would be willing to pay would be $250 USD and $500 USD, respectively (Deloitte, 2011).

**Compatibility** of existing values and consumer experiences when applied to the innovation. With electric vehicles, this is the degree to which the driving experience associated with the vehicle is compatible with the consumers driving needs. For electric vehicles to gain broad acceptance, they will need to provide the driver with an equal or superior driving experience to that provided by conventional vehicles.

**Complexity** refers to the behavioural changes associated with adopting the innovation, that is, how difficult or challenging the new technology is to understand and use. An example of the perceived complexity of electric vehicles is the fact that they require a new way to refuel the vehicle, using at-home or public chargers. Reducing complexity means overcoming public concerns of charging with electricity and its safety.

**Trialability** is the ability of a potential adopter to interact and experiment the new product before actually purchasing it. Given that electric vehicles are seen as an innovative technology, trialability means more than a simple test-drive around the block. As an example, in 2010, BMW conducted a leasing experiment in which it provided the opportunity for customers in Los Angeles and New York/New Jersey to lease its MINI E BEV; following participation in the trial activity, 71% of participants indicated an increased likelihood of purchasing a BEV (Turrentine, Garas, Lentz, & Woodjack, 2011). However, in the BMW case, trialability involved signing a one-year lease at $850 per month – an expensive proposition for some potential adopters. Brief test-drives with owners of electric vehicles are not likely to assuage concerns concerning relative advantage and compatibility.

The BMW study also raised another issue, a strong majority of participants indicated they supplemented their BEV usage with a second car – opting to use a non-electric vehicle in situations where range was a concern (Turrentine, Garas, Lentz, & Woodjack, 2011). Purchasing a second vehicle as a backup for the electric vehicle could prove to be too expensive for many would-be purchasers.

**Observability** is the opportunity afforded to both the public and potential adopters to observe the product being used. In this respect, electric vehicles are challenging since they look much the same as any other vehicle on the road. In terms of everyday use, observability is likely highest for electric vehicles when charging or using dedicated parking infrastructure.
Public charging stations could be looked upon as a double-edged sword. First, the lack of electric vehicles means that public charging stations will be unused for long periods, raising questions about the use of public funds for their installation. Second, the time to recharge (compared to refueling a conventional vehicle) may be seen as being too long to some observers, especially if there are several vehicles waiting to recharge at the same time (Berman, 2014b).

Other reasons for the limited uptake of BEVs other than the Tesla in 2015 have been suggested. For example, the recent decline in the price of gasoline may have an impact on BEV sales, although the lack of significant marketing on the part of vehicle manufacturers and the promise of new vehicle technology may be contributing factors as well (Arcus, 2015; Kress, 2015).

6.3 Subsidies

Over the past number of years, governments in a variety of jurisdictions around the world have offered subsidies to offset the purchase price of electric vehicles (for details of subsidies and tax incentives in the United States, see (The Car Electric, n.d.)). Arguments for such subsidies and incentives are varied, but often are presented as ways to:

- Support industries that manufacturer electric vehicles or products such as charging stations (Kopperson, Kubursi, Livingstone, Nadeem, & Slykhuis, 2014).
- Meet vehicle emissions targets to protect human health or the environment, or both (Center for Sustainable Energy, 2015).
- Create a demand for electricity (PSE, 2015).
- Present the jurisdiction as an environmental leader (WA DoC, 2012).
- Reduce the need for foreign energy imports (EERE, 2011).
- Encourage electric vehicles to come to a jurisdiction (Sullivan, 2015a).
- Raise the profile of electric vehicles (Campbell, 2015).

Both Quebec and Ontario offer subsidies for the lease or purchase of electric vehicles and EVSEs. The Quebec government has incentives up to $8,000 per electric vehicle and $600 for an EVSE (Quebec, 2012), while the Ontario government’s incentives range between $6,000 and $14,000, depending on factors such as battery capacity, and the number of seats in the vehicle (Ontario, 2016).

The decision by the governments of Quebec and Ontario to support electric vehicles is understandable for at least two reasons:

- Given the low emissions intensities of their respective electricity systems (2.1 g CO$_2$e/kWh in Quebec and 41 g CO$_2$e/kWh in Ontario (Environment Canada, 2016)), large-scale replacement of CVs with PEVs will make an impact on transport emissions.
- Both Quebec and Ontario are attempting to develop electric-vehicle industries in their provinces—encouraging the purchase of electric vehicles is seen as one way in which this can be done.
6.3.1 Charging infrastructure

In some jurisdictions, vehicle manufacturers and electricity suppliers are also involved, either directly or indirectly, in the installation of EVSEs as they stand to benefit from the adoption of BEVs and PHEVs. Vehicle manufacturers such as Volkswagen and BMW have announced investments in non-proprietary EVSE infrastructure in the United States (Davies, 2015), while at the same time arguing for additional government support (VW, 2015). On the other hand, Tesla is installing their own stations with proprietary EVSE infrastructure.

The highest concentration of BEVs and PHEVs in the United States is on the Pacific Coast between Washington State and California. In response, and to encourage the uptake of electric vehicles, a network of EVSE stations are being installed along Interstate 5, dubbed the “West Coast Electric Highway” (WCGH, 2014); British Columbia is also involved in the project (WCGH, 2008). The installation of most EVSEs is subsidized by taxpayers (state or local governments) or ratepayers (electricity supply companies), or both. Examples of EVSE support include:

- A $500 rebate on a Level 2 charger from Puget Sound Energy (PSE, 2015).
- Washington State tax exemption for the installation, repair, alteration, or improvement of EV infrastructure or the sale of property used for EV infrastructure (AFDC, 2014).
- Portland General Electric Company will provide $14,000 per station for up to 20 D.C. charging stations and $2,250 per station for up to 40 Level 2 charging stations as Oregon’s portion of the West Coast Electric Highway (PGEC, 2013).
- A residential tax credit of up to $750 for the installation of alternative fuel recharging infrastructure, including electricity, in Oregon (ODOE, n.d.).
- Most electricity supply companies in California offer a number of different tariff options for residential EV charging, most use interval meters and seasonal TOU billing. For example, an EV owner purchasing electricity from Southern California Edison can be billed using either a single meter and the residential tariff or two meters and two tariffs (residential and EV); the weekday rate structures are shown in Figure 15. In order to encourage off-peak electricity usage, the overnight hours have the lowest cost (California electricity suppliers have a summer peak because of air conditioning).
By 2025, California plans to have 1.5 million zero-emission vehicles (ZEVs) on its highways to reduce its reliance on petroleum, improve local air quality, and reduce greenhouse gas emissions to 80% below 1990 levels by 2050 (GIWG, 2015). An increase in the number of both BEVs and PHEVs is seen as an integral part of the ZEV action program; in response, electricity suppliers such as PG&E, one of California’s major electricity suppliers, has announced plans for the installation of 25,000 Level 2 and 100 D.C. fast charging stations in northern and central California (PG&E, 2015). The total cost of PG&E’s plan is estimated to be over $650 million, to be covered by PG&E ratepayers (the estimated cost to residential customers is 70 cents per month between 2018 and 2022 (PG&E, 2015)) (Cole, 2015). If approved by state regulators, PG&E would provide the EVSE free-of-charge to property owners, but retain ownership of the equipment; the maintenance and management of the EVSEs as well as billing would be the responsibility of the property owners, while PG&E would supply the electricity.

Since neither charging stations nor electricity is free, some EVSE stations are billing drivers for charging their vehicles (Chargepoint, 2015). Prices vary, but are typically calculated by hour and the type of charger; for example, a $2.00 per hour charge with a 6.6 kWh Level 2 charger amounts to about $0.30 per kWh. Making electricity freely available to electric vehicle owners has encouraged some BEV and PHEV owners to do a minimum charge at home and then find nearest no-cost charger to charge their vehicle (Berman, 2014c).

### 6.3.2 Nova Scotia – Charging infrastructure

Unlike a number of other provinces, the Nova Scotia government does not offer a direct subsidy for the purchase of electric vehicles, although in 2013, it awarded two grants totaling $47,000, to offset the cost of twelve AC charging stations across the province and a fast DC charging station at the Truro Power Center (NS DOE, 2013). Recipients of an AC charging station are expected to
pay $1,200 for the installation and are responsible for paying the cost of any electricity consumed for at least a year, estimated at $1.50 per charge (Sullivan, 2015b).\(^\text{16}\)

### 6.3.3 Nova Scotia – Electric vehicles

One argument for subsidizing BEVs directly in Nova Scotia is that they have lower levels of emissions per kilometre than either CVs or HEVs. While the emissions argument is true, as was shown in Table 16, when it comes to subsidies, it is useful to select a metric to determine the relative cost of the subsidy; a common approach is to consider the cost per tonne of CO\(_2\) reduction, obtained from the value of the subsidy and the difference in emissions over the operating lifetime of, for example, a CV and an EV.

In Table 16, the difference in emissions between a Mirage and a BMW i3 driven 20,000 a year over an eight-year period (from 2015 to 2022) would amount to about 7.68 tonnes of CO\(_2\).\(^\text{17}\) A subsidy of $1,000 would cost about $130 per tonne. This value compares favourably with the $0.17/kWh that Nova Scotians pay to subsidize wind, which amounts to about $328 per tonne; however, as wind subsidies decline (for example, $0.085/kWh or about $164/tonne), electric vehicle subsidies become less attractive.\(^\text{18}\)

Figure 16 shows the amount paid to reduce one-tonne of CO\(_2\) emissions by replacing a Leaf with a Civic. The amount depends on the distance driven each year (5,000 km/year to 30,000 km/year) over the eight years and the cost of the subsidy per vehicle ($1,000, $5,000, and $10,000). For example, purchasing a Leaf rather than a Civic with a subsidy of $5,000 would result in a difference of 2.69 tonnes of emissions if the vehicle was driven 5,000 km/year, the equivalent to $1,861/tonne in subsidies, while the subsidy would amount to $620/tonne if the same vehicle was driven 30,000 km/year, with 16.1 tonnes fewer emissions than the CV. In either the $5,000 or $10,000 case, it would be more cost effective for the province to subsidize wind-electricity than electric vehicles.

\(^{16}\) The $1.50 per charge cost appears to be based on a 10kWh charge at NSP’s residential rate of $0.149/kWh.

\(^{17}\) Eight years is assumed to be the lifetime of the vehicle.

\(^{18}\) NSP’s average emissions between 2015 and 2022 are estimated to be 518 g/kWh (518 kg/MWh or 0.518 t/MWh). The wind-electricity subsidy of $0.17/kWh ($170/MWh) will amount to $\frac{170}{0.518} = \frac{170}{0.518} \text{ t/MWh}$ or $328/tonne over this period.

It has been suggested that the wind-electricity subsidy used here is too high (S. Pushkarna, personal communication, 15 September 2016). However, a lower subsidy only makes it more attractive to subsidize wind-electricity than electric vehicles, as shown in Figure 16.
Although the difference in emissions between a Leaf (BEV) and Prius (HEV) is relatively small (see Table 16), the cost per tonne of emissions reduction is higher for a Prius than for a Leaf when replacing a Civic. For example, in Table 20, a Leaf driven 20,000 km/yr would emit 10.75 tonnes less CO₂e than a Civic (CV) over eight years, whereas the Prius would emit 8.8 tonnes less, meaning that a subsidy of $5,000 would cost $465 and $569 per tonne, respectively.

Table 20: Cost of reducing a tonne of emissions from the Leaf and Prius compared to Civic (2015-2022)

<table>
<thead>
<tr>
<th>Distance driven (km/yr)</th>
<th>10,000</th>
<th>20,000</th>
<th>30,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civic vs.</td>
<td>Leaf</td>
<td>Prius</td>
<td>Leaf</td>
</tr>
<tr>
<td>Emissions reduction (t)</td>
<td>5.37</td>
<td>4.40</td>
<td>10.75</td>
</tr>
<tr>
<td>Subsidy</td>
<td>$1,000</td>
<td>$186</td>
<td>$227</td>
</tr>
<tr>
<td></td>
<td>$5,000</td>
<td>$930</td>
<td>$1,137</td>
</tr>
<tr>
<td></td>
<td>$10,000</td>
<td>$1,861</td>
<td>$2,275</td>
</tr>
</tbody>
</table>

The results show that the lower the subsidy, the less it costs to pay for a tonne of emissions reduction. However, the lower the subsidy, there is less of an incentive for people to purchase an EV. Similarly, the cost per tonne of reduction declines the more the vehicle is driven; however, since there is no guarantee of the total distance the vehicle will be driven, it is difficult to predict what the actual reductions (and hence subsidy) would be, especially if the driver opted to use a CV during the winter months.

If the price of an electric vehicle with a subsidy is still beyond the average price Nova Scotians pay for new vehicles, the beneficiaries of any subsidy would likely be those who could probably afford the vehicle in the first place. This raises the prospect of individuals or groups who were
already planning to purchase a BEV or PHEV acting as economic free-riders and using the subsidy to purchase a potentially more expensive vehicle (Johnson, 2005).

While one can make arguments in favour of subsidies for BEVs, equally strong arguments can be made against subsidies; for example, the need for more urban transit in response to increasing urban densification in Halifax (Stantec, 2013), the decline in automobile use in some major cities (Moss, 2015), and the effects of ageing populations on car use (Newman & Kenworthy, 2011).

6.4 Road taxes

At present, although a large portion of the cost of many of the charging stations installed in the province are paid for by Nova Scotians, electric vehicles driven on Nova Scotia’s road network do not pay road taxes. While there are many arguments against taxing electric vehicles for their road use (including electric vehicles typically have less emissions per kilometre than their conventional counterparts (Built By Michigan, 2015), there are few BEVs on the road (Built By Michigan, 2015), BEVs result in macroeconomic cost savings (Anonymous NSP reviewer, personal communication, 18 December 2015), and they improve energy security (AFDC, 2015)), the fact is road taxes are, as the name suggests, for roads not the environment or potentially improving energy security. As road tax revenues decline due to declining vehicle usage in the United States (Pyper, 2014), a growing number of state legislatures are introducing fees to generate revenues from electric vehicles using state highways (Hartman, 2015).

Given the condition of Nova Scotia’s roads, it is reasonable to assume that the province will need to develop an equitable program of road taxes that includes electric vehicles. However, taxing electric vehicles for their use of the province’s road network presents two problems. The first is how much to charge for the road use and the second is how to collect the tax.

Gasoline and diesel road taxes are straightforward to administer and collect since most vehicles purchase their fuel with the applicable taxes already included in the price, from vendors who collect the tax. The electricity used in electric vehicles could be taxed at regulated charging stations designed to collect the tax as part of the sale; however, vehicles charged at an unregulated location (such as a residence or a place of work) cannot be taxed easily at present in Nova Scotia.

Despite this, there are ways in which road taxes can be collected from electric vehicles; for example:

- A one-time charge could be applied to the vehicle when it is sold to a consumer, based on expected road use and life of vehicle. However, this policy would not work for vehicles purchased out-of-province and would be unfair to drivers leaving Nova Scotia to work or travel in other jurisdictions where an electric-vehicle road tax was collected.

- Toll roads could be used to collect road taxes; however, the tolls collected for a toll road are often earmarked for the maintenance of the road being tolled rather than all roads (Lindsey, 2007). Moreover, vehicles not driven on toll-roads would not be subject to the road taxes.

- Many, if not all, electric vehicles have wireless communication capabilities (for example, see (Moritz & Ohnsman, 2013; Nissan, n.d.; Onstar, n.d.)) which could be used for collecting taxes. By relaying the vehicle’s odometer information as well as its 17-digit VIN (Vehicle Identification
Number) to a central road operations center, the tax could be collected from the owner using, for example, credit card information. This could be done at any charging station with communication facilities. In situations where the charging takes place at a location without communications, the vehicle could store the charging information and relay it to a central road operations center when the opportunity arose.

The above proposals notwithstanding, it is widely agreed that fuel consumption is a poor proxy for road use (Lindsey, 2007). An alternative is to collect a road-usage tax based on, for example, vehicle-type, or the average vehicular road use in the province. A fairer alternative would be to determine the vehicle’s actual road use by comparing the vehicle’s past and current odometer values, something already done in Nova Scotia during the vehicle inspection (Nova Scotia, 2009). Such a policy could be applied to all vehicles, electric or otherwise, as part of the license renewal process (Built By Michigan, 2015).

6.5 Nova Scotia – Time-of-Use rates

At present, Nova Scotia Power offers time-of-use rates for consumers using “electric-based heating systems utilizing Electric Thermal Storage (ETS) equipment, and electric in-floor radiant heating systems utilizing thermal storage and appropriate timing and controls” (NSP, 2016). The rates are intended to encourage customers to charge their storage heaters during the overnight hours (11pm to 7am) during the months of December to February, while these consumers also have lower-cost electricity during the overnight hours between March and November (see Figure 17).

![Figure 17: Nova Scotia Power’s Domestic Service Time-of-Day Tariff (NSP, 2016)](image)

These rates are not available to EV users who do not use storage heaters. If the rates were available, the energy cost associated with driving an EV would decline by almost half for anyone charging their vehicle exclusively during the overnight hours.
6.6 Improving energy security

For battery electric-vehicles to improve Nova Scotia’s energy security, they must reduce the risk associated with the existing fleet of light-duty passenger vehicles. Broadly speaking, there are three major threats associated with continued use of conventional vehicles in Nova Scotia, all related to the fact that CVs rely on petroleum products:

**Availability.** Although Nova Scotia may have offshore reserves of crude oil (Nova Scotia, n.d.), these must be extracted and shipped to a refinery for processing. The petroleum products that Nova Scotia consumes are neither refined here nor, at present at least, sourced from Nova Scotia.\(^1\)

Relying on petroleum products that have been refined elsewhere is typically not a problem, given the logistics in the petroleum market. However, this does not mean that mistakes won’t occur, as Nova Scotians learned late summer of 2015 when there was an unexpected shortage of gasoline (CBC, 2015).

The risk of a petroleum supply shortfall is very low, given that the likelihood of the event is rare and the vulnerability is low because of the existing supply chain.

**Affordability.** The price of petroleum products is determined by both world oil markets and the refining costs. Over the past 20 years, this has proven to be somewhat volatile; the decision by Saudi Arabia and other oil producers to oversupply the world with oil has seen prices drop markedly (IEA, 2015). How long prices will remain depressed is anyone’s guess; for example, continued rising tensions in the Middle East could trigger a price increase, but even this may be short-lived, given the world’s overcapacity of supply.

The risk of an increase in the cost of gasoline over the medium-to-long term is moderate to high, not because of Middle East tensions, but due to the likelihood of carbon pricing being introduced in the province (see section 6.8), either in the form of carbon taxes or emissions trading.

**Acceptability.** As this report has shown, road transportation is carbon-intensive. The threats associated with anthropogenic climate disruption are expected to be high to very-high over the long-term, making the continued use of carbon-intensive fuels a high risk.

Reducing these risks will require energy policies that restrict future road transportation to low-carbon energy sources (Hughes, 2009). This report has shown how, if Nova Scotia Power achieves its 2030 emissions targets, per-kilometer emissions from BEVs will be about half that of CVs (see Figure 13). While the widespread adoption of BEVs would help Canada meet its Paris Agreement commitments, achieving this goal is not without its risks:

**Availability.** BEVs will be a new load for Nova Scotia Power, requiring Nova Scotia Power to upgrade parts of its grid and roll-out a province-wide smart grid. If Nova Scotians increase their use of electricity as a source of low-emissions energy, meeting this demand could

---

\(^{19}\) Even if Nova Scotia were still to have a refinery that would not guarantee that Nova Scotian crude oil would be refined at it, given that both crude oil and its refined products are fungible. Moreover, one of the reasons that Nova Scotia’s refinery was shuttered was its inability to process the increasingly heavier crudes that were appearing on the market at the time.
become an issue if demand for electricity from new services cannot be met during, for
example, the winter peak.

Affordability. While the per-kilometer cost of electricity is less than that of liquid fuels, BEVs are,
at present, more expensive than CVs. If the CV-BEV cost differential cannot be addressed,
there is a risk that transportation emissions will not decline as rapidly as required.

Acceptability. Despite the anticipated decline in Nova Scotia Power’s emissions, there are still
other acceptability risks. For example, to ensure that BEVs can be used for year round
transportation needs, they will require a method of cabin-heating and sufficient storage to
avoid using CVs for winter driving. If this cannot be done, there would be a risk that the
emissions associated with transportation would be higher than anticipated.

6.7 Public transport: Electric buses

The focus of this report has been on four different categories of light-duty vehicle that use a liquid
fuel or electricity, or both. The different vehicles were compared in terms of their availability,
affordability, and acceptability. The state of Nova Scotia’s economy, its ageing population, and
its median family income suggest that the uptake of light-duty passenger electric-vehicles may
be far slower than is needed to reduce Nova Scotia’s greenhouse gas emissions and contribute
to Canada’s commitment to the Paris Agreement.

Although light-duty passenger vehicles are one of the single largest end-use sources of
greenhouse gas emissions in the province, there are other types of battery electric-vehicle which
can help improve Nova Scotia’s environmental acceptability, including commercial vans and
passenger buses (for example, see (Nissan, n.d.; BYD, 2015)). Replacing existing commercial vans
and passenger buses that use diesel as a fuel with their battery-electric equivalent can also
contribute to the reduction of greenhouse gas emissions and offers other potential benefits,
including reduced particulate matter, lower emissions of nitrogen oxides, and quieter streets.

Of particular interest to readers of this report is the battery-electric passenger bus. Like the light-
duty electric-vehicles discussed in this report, the emissions associated with electric passenger-
buses are less than their non-electric counterparts and the fuel costs are lower (Kane, 2013). Moreover,
their size allows additional battery storage, increasing the time between charges (Field, 2015). At least one manufacturer has addressed the cold-weather operation issue by
including a small liquid-biofuel heating system in the bus (New Flyer, n.d.). Battery-electric buses
are also way to address some of the public’s concerns regarding electric vehicles described in
section 6.2; for example, riding an electric bus as well as seeing them in operation on the street
would eventually become second nature.

By supporting electric passenger-buses, Nova Scotia Power and the province would not only raise
the profile of electric vehicles, potentially encouraging their adoption, it would also contribute to
the reduction of greenhouse gas emissions in the transportation sector, albeit in a minor way
given the fuel demand of the bus fleet in the province. In jurisdictions with a sufficiently large
fleet, battery-electric buses could justify the addition of more variable sources of renewable
electricity to the grid as the buses could smooth out periods of over-production (by charging from
the grid) or under-production (by supplying electricity to the grid).
6.8 Carbon pricing

Barring a last-minute settlement or the introduction of some form of emissions-trading scheme, Nova Scotia, will be expected to implement a federally-mandated carbon-levy on the sale of energy products (such as electricity, gasoline, and light fuel oil) from 2018 until 2022. The price of carbon will be set at $10 per tonne of CO$_2$e in 2018, increasing by $10/tonne per year until 2022, when it will be $50/tonne. The approximate cost per litre of the carbon-levy each year is shown in Table 21.

Table 21: Cost per litre of carbon-levy

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$10/tonne</td>
<td>$20/tonne</td>
<td>$30/tonne</td>
<td>$40/tonne</td>
<td>$50/tonne</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>$0.027</td>
<td>$0.054</td>
<td>$0.080</td>
<td>$0.107</td>
<td>$0.134</td>
</tr>
<tr>
<td>Gasoline</td>
<td>$0.023</td>
<td>$0.046</td>
<td>$0.069</td>
<td>$0.092</td>
<td>$0.116</td>
</tr>
</tbody>
</table>

The revenues generated from the sale of products affected by the carbon-price are to be allocated as each provincial government sees fit (Canada, 2016). However, it is assumed that low-income households will be supported with rebates to offset the impacts of the increased cost of energy associated with the carbon-price (Ecofiscal, 2016).

This section considers the possible impact of using the carbon-levy from the sale of gasoline and diesel for light-duty vehicles (i.e., automobiles) and trucks on both the purchase of electric vehicles and the associated decline in greenhouse gas emissions. Only light-duty vehicles and trucks are included as these are seen as the most likely candidates for being replaced by BEVs.

In 2014, about 20% or 3,401 kt of Nova Scotia’s 16,600 kt of greenhouse gas emissions came from road transportation (see Table 22). The total emissions from light-duty vehicles and trucks amounted to 2,184 kt (i.e., the sum of Light-Duty Gasoline Trucks, Light-Duty Gasoline Vehicles, Light-Duty Diesel Vehicles, and Light-Duty Diesel Trucks).

Table 22: Nova Scotia’s road transportation emissions in 2014

<table>
<thead>
<tr>
<th>Category</th>
<th>Emissions (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light-Duty Gasoline Trucks</td>
<td>1,160</td>
</tr>
<tr>
<td>Heavy-Duty Diesel Vehicles</td>
<td>1,060</td>
</tr>
<tr>
<td>Light-Duty Gasoline Vehicles</td>
<td>982</td>
</tr>
<tr>
<td>Heavy-Duty Gasoline Vehicles</td>
<td>141</td>
</tr>
<tr>
<td>Light-Duty Diesel Vehicles</td>
<td>35.3</td>
</tr>
<tr>
<td>Propane and Natural Gas Vehicles</td>
<td>12.0</td>
</tr>
<tr>
<td>Light-Duty Diesel Trucks</td>
<td>6.7</td>
</tr>
<tr>
<td>Motorcycles</td>
<td>4.4</td>
</tr>
<tr>
<td>Total</td>
<td>3,401</td>
</tr>
</tbody>
</table>

Assuming that the total emissions for light-duty vehicles and trucks in 2018 are the same as those in 2014, the carbon levy of $10/tonne would generate about $21.8 million in revenue. If Nova Scotia opts to return part of this to households earning less than the current Nova Scotian
average household income of $71,582, then 60% of Nova Scotian households (roughly 246,000) will receive a rebate (Ecofiscal, 2016). Revenues from the carbon-levy applied to heavy-duty diesel vehicles and heavy-duty gasoline vehicles are not used in these calculations because the trucking industry will be facing their own set of challenges with the carbon-levy.

The size of the rebate depends on the policy adopted by the government. For example, in Alberta, the gasoline rebate in 2017 will be $135 per household for a $20/tonne carbon-levy, increasing by 50% to $203 for a $30/tonne carbon-levy in 2018 (Alberta, 2016). If the $10/tonne rebate of $67.50 is used for 2018 (see footnote 20), the total rebate cost would be $16.6 million. Resulting in $5.2 million being available for subsidizing electric vehicles; for example, a $5,000 rebate could subsidize 1,047 vehicles, whereas $10,000 could subsidize 523 vehicles. The total emissions actually reduced because of the subsidy will depend on the types of vehicles and their expected annual emissions.

In the following example, a $10,000 rebate is available to owners of CVs to purchase BEVs. It is assumed that Civics (or their equivalent) are replaced by Leafs (or their equivalent) and the vehicles are driven 20,000 km/year. The annual emissions associated with the vehicles and the emissions reduction caused by replacing a Civic with a Leaf are shown in Table 23; for example, in 2019, driving a Leaf rather than a Civic would result in an emissions reduction of 1.452 tonnes of CO2e, with an BEV-to-CV emissions-intensity ratio of 55.4% (i.e., the Leaf’s emissions intensity is 55.4% of the Civic’s).

<table>
<thead>
<tr>
<th>Table 23: Annual emissions and reduction (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civic (CV)</td>
</tr>
<tr>
<td>Leaf (BEV)</td>
</tr>
<tr>
<td>Reduction (t)</td>
</tr>
<tr>
<td>BEV:CV ratio</td>
</tr>
</tbody>
</table>

The outcomes of the example are shown in Table 24. Line 1 is the annual carbon-levy, while line 2 lists the total road emissions from light-duty gasoline and diesel vehicles and trucks for the year, starting at 2,184 kt (the total emissions in 2014, used as the baseline) and decreasing by a

20 Alberta’s carbon-levies and rebates have been set for 2017 and 2018, with both the 2018 levy and rebate to increase by 50% over the 2017 values: the levy increases by 50% from $20/tonne to $30/tonne and the rebate increases by 50% from $135 to $203 (Alberta, 2016). If the ratio of the annual increase in carbon-price is applied to the annual rebate, the $10/tonne rebate would be $67.50 (half of Alberta’s $135 rebate since the $10/tonne carbon-levy is half the $20/tonne carbon-levy). The following table lists the rebates for the federal government’s carbon-levy using the carbon-levy increase-ratio starting in 2018:

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-levy (per tonne)</td>
<td>$10</td>
<td>$20</td>
<td>$30</td>
<td>$40</td>
<td>$50</td>
</tr>
<tr>
<td>Ratio (carbon-levy annual growth)</td>
<td>-</td>
<td>2</td>
<td>1.5</td>
<td>1.333</td>
<td>1.25</td>
</tr>
<tr>
<td>Rebate (per household)</td>
<td>$67.50</td>
<td>$135.00</td>
<td>$202.50</td>
<td>$270.00</td>
<td>$337.50</td>
</tr>
</tbody>
</table>

21 For example, the number of vehicles that could be subsidized from $5.2 million at $5,000 per vehicle would be $5.2 million / $5,000 per vehicle = 1,047 vehicles.
function of the current and previous year’s emissions reduction (line 8). The expected revenue (line 3) is the product of the carbon-levy (line 1) and the total road emissions (line 2). The individual household rebate and the total rebates for all qualifying households are listed in lines 4 and 5. The difference between the revenue (line 3) and the household rebates (line 5) is the vehicle subsidy (line 6); line 7 is the total number of vehicles that can be purchased with the $10,000 subsidy. The emissions reduction for the number of vehicles purchased (line 8) increases each year and is a function of the product of the number of vehicles purchased and the annual reductions (shown in Table 23).

Table 24: Expected reductions from the purchase of BEVs supported by $10,000 subsidy (vehicles driven 20,000 km/year)

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Carbon-levy ($/tonne)</td>
<td>$10</td>
<td>$20</td>
<td>$30</td>
<td>$40</td>
<td>$50</td>
<td></td>
</tr>
<tr>
<td>2 Total road emissions (kt)</td>
<td>2,184</td>
<td>2,182</td>
<td>2,180</td>
<td>2,178</td>
<td>2,174</td>
<td>9.9</td>
</tr>
<tr>
<td>3 Revenue (MM$)</td>
<td>$21.8</td>
<td>$43.7</td>
<td>$65.5</td>
<td>$87.2</td>
<td>$108.9</td>
<td>$327.1</td>
</tr>
<tr>
<td>4 Rebate (per household)</td>
<td>$68</td>
<td>$135</td>
<td>$203</td>
<td>$270</td>
<td>$338</td>
<td>$1,012.5</td>
</tr>
<tr>
<td>5 Household rebates (MM$)</td>
<td>$16.6</td>
<td>$33.2</td>
<td>$49.8</td>
<td>$66.4</td>
<td>$83.0</td>
<td>$249.1</td>
</tr>
<tr>
<td>6 Vehicle subsidy (MM$)</td>
<td>$5.2</td>
<td>$10.5</td>
<td>$15.7</td>
<td>$20.8</td>
<td>$25.9</td>
<td>$78.0</td>
</tr>
<tr>
<td>7 Vehicles purchased</td>
<td>523</td>
<td>1,046</td>
<td>1,566</td>
<td>2,080</td>
<td>2,586</td>
<td>7,800</td>
</tr>
<tr>
<td>8 Emissions reduction (kt)</td>
<td>0.41</td>
<td>1.17</td>
<td>1.98</td>
<td>2.78</td>
<td>3.52</td>
<td>9.9</td>
</tr>
</tbody>
</table>

In this example, between 2018 and 2022, road emissions from the increased use of subsidized BEVs would have declined by 9.9 kt (in comparison, between 2010 and 2014, road emissions fell by 454 kt (Environment Canada, 2016)).

Although 7,800 CVs were replaced by BEVs during this period, the limited impact on the overall total road emissions can be explained by the high emissions intensity of the electricity used. A lower emissions intensity in a jurisdiction such as Quebec or Ontario would have resulted in a more significant decline in road emissions, as discussed in section 5.1.3.

A Leaf purchased in 2018 to replace a Civic with an eight-year lifetime in Nova Scotia would result in a total reduction in emissions of 11.8 tonnes at a cost of about $844/tonne (using NSP’s emissions projections for this period).

Different levels of vehicle subsidy affect the revenue generated from the carbon levy (as emissions decline, the revenue declines), the vehicle subsidy (as the revenue declines, the subsidy declines), and the total emissions reduction. Table 25 is a comparison of three different vehicle-subsidies, $5,000, $10,000, and $15,000, for vehicles driven 20,000 km per year in Nova Scotia.

---

22 Each year’s emissions reduction (line 8) is based on the assumption that vehicle purchases are distributed evenly throughout the year, meaning that vehicles sold at the beginning of the year reduce emissions more than those sold at the end of the year. In this case, vehicles sold in January reduce emissions for 12 months, in June for six months, and in December for one month, giving a total of 78 months of possible reductions out of a maximum possible 144 months (i.e., had they all been sold in January), or 54%. Of the total possible annual emissions reduction from the vehicles sold in a year, 54% are applied in the current year and 46% are applied in the following year.
Table 25: Comparison of effects of different vehicle subsidies
(vehicles driven 20,000 km/year between 2018 and 2022)

<table>
<thead>
<tr>
<th>Subsidy per vehicle</th>
<th>Carbon-levy revenue (MM$)</th>
<th>Household rebates (MM$)</th>
<th>Vehicle subsidy (MM$)</th>
<th>Number of vehicles purchased</th>
<th>Emissions reduction (kt)</th>
<th>Lifetime cost per tonne</th>
</tr>
</thead>
<tbody>
<tr>
<td>$5,000</td>
<td>$326.6</td>
<td>$249.1</td>
<td>$77.5</td>
<td>15,498</td>
<td>19.6</td>
<td>$422</td>
</tr>
<tr>
<td>$10,000</td>
<td>$327.1</td>
<td>$249.1</td>
<td>$78.0</td>
<td>7,800</td>
<td>9.9</td>
<td>$844</td>
</tr>
<tr>
<td>$15,000</td>
<td>$327.2</td>
<td>$249.1</td>
<td>$78.2</td>
<td>5,212</td>
<td>6.6</td>
<td>$1,265</td>
</tr>
</tbody>
</table>

The table shows:

- Although more vehicles can be purchased at lower subsidies per vehicle, there is little difference in the carbon-levy because the actual emissions reduction is quite small relative to the total road emissions from gasoline and diesel light-duty vehicles (about 2,100 kt per year).

- While lower subsidies do result in a greater decline in emissions, if the subsidy is perceived to be too low (making the vehicle purchase cost higher), potential buyers may be discouraged from purchasing a BEV; on the other hand, increasing the subsidy may result in more purchases, but the emissions reduction would decline correspondingly.

- Road transport emissions are limited by the rate at which BEVs are replacing CVs and Nova Scotia Power’s emissions intensity.

- The household rebates (i.e., the product of the total number of households and the rebate per household) are equal in all cases as the number of households that benefit from the rebate remain constant.

- The lifetime cost per tonne refers to the cost-per-tonne of emissions reduction at a given level of subsidy after driving the vehicle for eight years in Nova Scotia; not surprisingly, the lower the subsidy, the lower the cost-per-tonne.

7 Concluding remarks

Much of the economic expansion in developed western countries after the Second World War can be attributed to the growth in demand for the automobile. A key contributor to this growth has been the availability of low-cost liquid fuels. However, this growth has not been without its problems: health and safety issues, environmental concerns, and fuel supply and price volatility have all contributed to changes in the design of the automobile. Despite this, two fundamental components of the automobile have remained unchanged for more than a century: the energy source is still a liquid fuel and the conversion process is still the internal combustion engine. Over the past 20 years, an increasing number of automobile manufacturers have developed vehicles that rely on electricity for propulsion, thereby reducing the need for liquid fuel (the hybrid-electric vehicle) or eliminating it altogether (the battery-electric vehicle).

This report has examined some of the issues relating to the adoption of electric vehicles in a jurisdiction using a set of energy-security indicators, notably the availability of energy for the vehicle to meet the driver’s transportation requirements, the affordability of the fuel (i.e., electricity) and the vehicle, and the acceptability of the emissions associated with driving the
vehicle. In addition, the report has also considered related issues, such as subsidies, challenges to the uptake of electric vehicles, and road pricing.

The indicators were applied to electric vehicles in general terms and, when possible, applied to Nova Scotia. From this the report discussed:

**Availability.** The availability of the vehicle’s energy source (a liquid fuel or electricity) is clearly essential to the vehicle’s operation. In developed jurisdictions, the availability of electricity is not considered a risk. Since most BEVs are designed for distances of about 100km, they are often used for commuting, thereby allowing the driver to charge at home, or in some cases, both at home and work. The effect of cold temperatures on BEV range is well known, requiring additional charging for both auxiliary heating and to offset a decline in battery efficiency; using a CV during the winter months could reduce the environmental benefits associated with BEVs.

In terms of Nova Scotia, it was shown that at present, Nova Scotia Power should have little difficulty in meeting the electricity demands of the limited number of BEVs in the province. However, if widespread adoption of BEVs was anticipated in a particular area of the province, there should be extensive three-phase load flow, voltage unbalance, and transformer loading studies conducted on the appropriate sections of the distribution grid to assess the overall potential impact of the infrastructure on the regional grid. If the number of BEVs were to increase substantially, it would be necessary for Nova Scotia Power to upgrade sections of the province’s grid, to institute coordinated charging controlled by a smart grid and offering customers time-of-use or real-time billing.

Nova Scotia’s winter weather could be expected to increase the number of charges required by longer-distance commuters using BEVs, increasing their commuting time (if charging is during the commute is required) and adding to Nova Scotia Power’s winter load.

**Affordability.** Affordability can be discussed on a number of levels. In terms of operating costs (i.e., energy cost per kilometre), BEVs can be considerably less expensive to drive than CVs; this is in part because of fuel taxes applied to liquid fuels but not electricity and, in some jurisdictions, BEVs can be recharged at no cost. However, as electricity costs increase, the price differential is reduced as the efficiency of the CV improves. Energy costs notwithstanding, the most significant barrier to the widespread adoption of BEVs at present is their cost.

In Nova Scotia, the price of electricity (relative to the cost of a liquid fuel) makes driving a BEV less expensive than driving a CV (the difference could be expected to decline if the BEV was driven during the winter months); moreover, publically financed charging-stations do not require the driver to purchase the electricity, reducing the cost of driving it even further. However, when comparing the base price of a BEV and its home-charger with the average price paid by Nova Scotians for new vehicles, the annualized cost of the CV is less. This could be an issue in Nova Scotia, given the state of the provincial economy, its demographics, and average family income.

**Acceptability.** Perhaps the strongest argument for the purchase of a BEV is that, depending on the electricity supplier’s energy mix, it can have lower per-kilometre emissions. The projected
changes to Nova Scotia Power’s generation mean that BEVs will become an increasingly better choice when it comes to emissions-per-kilometre than either HEVs or CVs.

At present, there are apparently very few BEVs or PHEVs in Nova Scotia. Given their price, it seems unlikely that they will become the vehicle-of-choice for most Nova Scotians for the foreseeable future; with the exception of the west coast of North America, this appears to be the case in the United States as well. In light of this, subsidizing the installation of charging stations or the purchase of vehicles will benefit the very few Nova Scotians who are able to purchase such a vehicle.

If Nova Scotia Power (or its parent, Emera) wants to develop a network of publically accessible EVSEs, as PG&E is doing in California, they should make a commitment to it, through the proper regulatory channels. Similarly, if Nova Scotia Power wants to increase the number of BEVs in the province, it should develop a plan to roll-out a smart-charging program with options for time-of-use or real-time pricing. Whether there would be sufficient interest to justify such an expense would be for the public and regulators to decide.

While the availability of funds from a carbon-levy on the sale of gasoline and diesel could be used to encourage the purchase of PEVs, the actual impact on the province’s emissions will not be that great, given the number of vehicles that can be purchased and Nova Scotia Power’s present emissions intensity.

The electrification of transportation is not restricted to automobiles. For example, the provincial government and Nova Scotia Power might consider supporting the introduction of battery-electric buses. This will help reduce some of the problems with existing diesel buses, such as noise and particulate emissions, lower the cost of operating public transportation, and raise the profile of battery-electric vehicles. Ultimately, it is up to the provincial government to decide whether the province should develop a program encourage the uptake of battery-electric vehicles as part of a strategy to contribute to the overall reduction in Nova Scotia’s greenhouse gas emissions. However, rather than making it a one-off, ad hoc policy, it should be part of a new energy strategy that defines the province’s energy future, not only targeting electrical generation and the transportation sector, but the on-going use of fuel oil for the heating of residential and commercial buildings as well.
References


http://www.builtbymichigan.org/electric-vehicles-are-paying-their-way


Calvi, L. (2015, April 30). Don't forget to plug it in! *Chronicle-Herald - Wheels - Lady Drive.*


http://climate.weather.gc.ca/climateData/hourlydata_e.html?timeframe=1&Prov=NS&StationID=50620

http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=6358&lang=e&StationName=halifax&SearchType=Contains&stnNameSubmit=go&dCode=1


SCE. (2015a). SCE Introduces a New Residential Time-Of-Use Rate Plan. Retrieved August 26, 2015, from Southern California Edison: https://www.sce.com/wps/portal/home/residential/rates/residential-plan/lut/p/b1/rVXRcqlwFP2V9sHHyA1JCOWb7lortmqrdisvTlClGI0yOq2X7_BdXaLtrXulhlmcsm5B87jvRcr06tMBPrNBFFujiErIxVZ4Ldln_ZHkDbb2AmtBvQ6_q3PnQ4GMDYAOCNy4dqfms09E3-twA-G4DdKn13QqtUGXFspa45XSE7X


